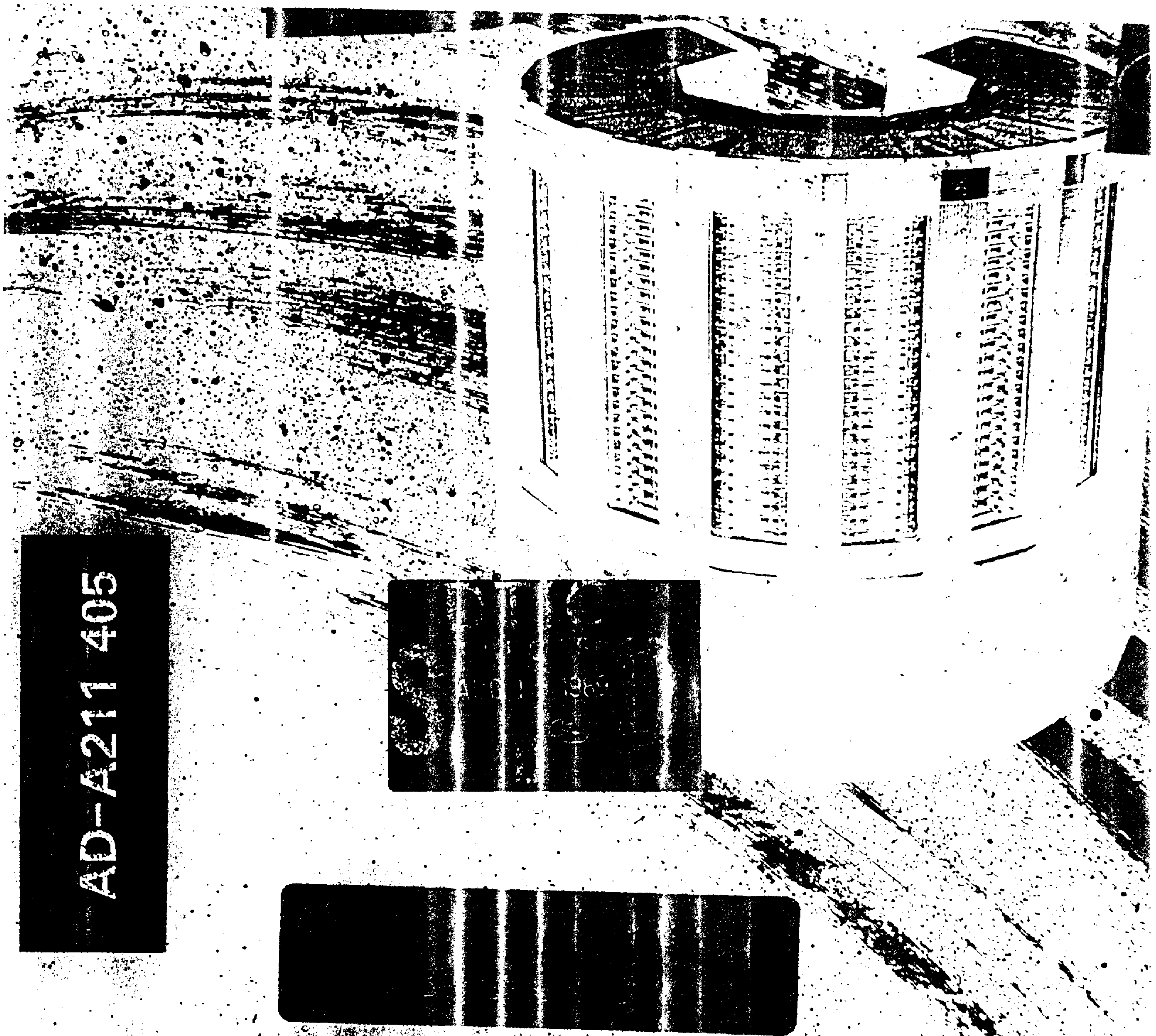

INTERNATIONAL COMPETITIVENESS

A National Security Perspective

MAJ RONALD H. DABROWSKI

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International Competitiveness

A National Security Perspective

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International Competitiveness
A National Security Perspective

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Foreword

The Gramm-Rudman-Hollings-driven national fiscal reality of the late 1980s and the early 1990s will serve to severely constrain the funds necessary to maintain a strong military posture. We will surely find that our nation's economic status in the increasingly competitive global marketplace will become one of the deficit reduction battles and will in turn drive the national defense "affordability" issue.

In this study, Maj Ronald H. Dabrowski provides a unique perspective of the past, present, and future status of our nation's economic machine. He presents a well-documented argument that the United States has experienced and will continue to experience a relative decline in its global power standing as other nations continue to prime their economic machines. Consequently, the national security ramifications of our loss of technological and economic dominance will be profound.

He postulates that if we as a nation wish to continue to exert a broad level of influence in world affairs, we must adapt ourselves to this new world order. More fundamentally, we in the Department of Defense must begin to consider the effects of our various expenditures and policies on our industrial base's ability to compete in the global market because it will be our performance in the global marketplace that will dictate our ability to shape and influence world events. This is not to say that such considerations should be the sole basis for action but rather that such inputs are critical to achieving long-term national security.

Although any paper that attempts to address economic, military, and political issues will inevitably present arguable conclusions, Major Dabrowski's findings should nonetheless serve as the basis of stimulating thought for our nation's present and future leaders. Those individuals planning on making a contribution toward our nation's military security will find this paper required reading.

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About the Author

MAJ RONALD H. DABROWSKI was the Command-Sponsored Research Fellow from the Air Force Communication Command (AFCC) at the Air University Center for Aerospace Doctrine, Research, and Education (AUCADRE) for 1987–88. He received a bachelor of science degree from Central Connecticut State University, a master's degree in business administration from the University of Missouri, and an education specialist degree from Central Missouri State University. He has also completed all required courses for a doctorate in public administration from the University of Alabama and is currently working on his dissertation. Following an operational tour with the Minuteman II weapon system, Major Dabrowski served contracting tours with the Air Force Systems Command and AFCC. He is a graduate of Air Command and Staff College and is presently the chief of the Acquisition Management Branch, the Joint Staff, in the Pentagon.

Preface

Having spent the past five years acquiring complex weapon and computer systems for the United States Air Force, I have been amazed at the level of complexity associated with bringing all the pieces of these systems together to turn out the required end product. While most individuals fail to realize the difficulty of such an effort, even more fail to appreciate the degree of foreign-source dependence on major subassemblies. This issue first received widespread public visibility during the oil embargoes of the 1970s and promises to take on increasing national importance well into the future as foreign firms become increasingly technologically advanced.

I am grateful to the Air Force Communications Command for giving me the opportunity to address our nation's foreign-source dependency problems, and I hope this paper will provide a basis for informing our present and future leaders about this complex issue. Special thanks is due the staff of the Airpower Research Institute, particularly Dr Stanley Spangler, my academic adviser; Hugh Richardson, my editor; and last, but certainly not least, Lt Col Manfred Koczur, chief of the Center for Aerospace Doctrine, Research, and Education research fellows.

On a more personal level, my deepest love and appreciation go to my wife Sandra, who willingly gave me the time and space to devote a full year to this paper while simultaneously attending Air Command and Staff College at Maxwell AFB, Alabama, and completing all the courses required for a doctoral degree at the University of Alabama.

RONALD D. DABROWSKI, Maj, USAF
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Introduction

Over the past two decades, the United States has been losing its technological leadership status in the world as a result of numerous internal and external factors. With our reliance on technological superiority to deter our numerically superior adversaries and drive our economic machine, this issue has taken on grave national security implications. Beyond the obvious military ramifications of being dependent on foreign sources for critical weapon system components, the economic consequences of our technological decline may prove even more significant to the Department of Defense (DOD) over the long run.

Specifically, if our technological leadership and economic strength continue to deteriorate relative to the rest of the world's powers, the nation's ability and willingness to support what are perceived to be high levels of DOD funding will certainly erode. In fact, we began to see such results in the budgets of the mid-1980s.

While DOD cannot reverse the nation's competitive decline single-handedly, the sheer size of our annual procurement budget provides us with significant leverage in the marketplace. It is therefore imperative that we fully comprehend the nature of economic competition throughout the world. Only through such an understanding can DOD help foster a healthy environment for the nation's strategic industries while avoiding shortsighted and counterproductive activity.

This paper has one primary goal: to provide the reader with a national security perspective on global economic competition and its implications on the continued ability to carry out our mission. Finally, although certainly not an intent of the paper, many of the competitiveness issues discussed compare our policies with those of our chief economic rival—Japan. Given that our two nations provide upward of 30 percent of the world's economic output, such an emphasis is understandably appropriate. Through such an understanding, those in position to make a difference today and in the future will keep this perceptive in mind when making day-to-day decisions.

Chapter 1

Status of the Industrial/Technological Base

During World War II, the United States was considered the "arsenal of democracy" due to its tremendous industrial and technological capabilities, which—once primed—helped ensure the Allies' ultimate victory. But this characterization of the United States as a superior economic and military power belies the fact that our history has consistently been one of erratic wartime industrial preparedness.

Past Experience

We have too often ignored the lessons of the past and found ourselves ill-prepared at the start of major conflicts. Consider the following facts. Even though the United States did not enter World War I until the war had been under way for several years, the nation was totally unprepared at the time of entry to support the effort logistically. Consequently, the majority of American weapons did not arrive in Europe in time to contribute to the victory. In fact, most American soldiers fought the war with British or French weapons. Deliveries of US weapons were limited to 145 pieces of 75-mm field artillery, one antiaircraft gun, 16 tanks, and 107 steel ships (of 1,741 ordered) before the armistice was signed.[1]

When the United States entered World War II, it was in better industrial shape than in 1917 because of increased preparedness resulting from its ongoing logistical support of the Allies. However, just as in World War I, it took a minimum of 1½ to 3½ years to reach full-scale production of most war materiel.[2] Our armaments production effort at the beginning of the Korean War was aided by the substantial inventory of conventional weapons and munitions left over from World War II. Still, the country encountered problems with industrial expansion. Again, the defense mobilization process was agonizingly slow, with two-thirds of the aircraft, guided missiles, tanks, trucks, and ammunition undelivered more than two years after orders had been placed.[3]

Following the Korean War, the United States increasingly relied on the nuclear "card" to deter our adversaries. Consequently, we allowed our conventional capabilities to deteriorate. Our comfortable reliance on nuclear deterrence was short-lived. Following the Soviet embarrassment during the Cuban missile crisis, the USSR substantially increased its nuclear capabilities throughout the 1960s and eventually attained parity (some would assert superiority) sometime in the 1970s. In addition to their nuclear buildup during this period, the Soviets also significantly increased their nonnuclear forces.

As this nation's reliance on its nuclear capability to deter all levels of conflict decreased, the likelihood of a conventional war increased. However, the political and fiscal unacceptability of having to maintain a larger standing conventional force to match the Soviet buildup, combined with our distasteful experience with wars of "attrition," prompted the national leadership to adopt a strategy of technological superiority to offset the numerical advantage of our adversaries. Still, even with our reliance on smaller quantities of high-tech weapons, existing inventories and surge capabilities are inadequate to sustain combat forces during a protracted conflict.

In fact, our industrial base readiness posture is in such poor shape that members of Congress, DOD, and the arms industry are in agreement that if a global war were to start today, the United States could not even duplicate the poor performance it demonstrated during previous conflicts.[4]

The primary obstacle to a surge capability stems from the fact that today's weapon systems have become very complex and are too dependent on specialized materials and processes for us to place reliance on the easy and rapid conversion of existing civilian industry to wartime production.[5]

Not only is our ability to surge during an international crisis in question, but even our continued ability to *maintain the required technological edge during* peacetime is in doubt. Dr Jacques S. Gansler, former deputy assistant secretary of defense for materiel acquisition, assessed the situation this way in 1985:

> America currently is the world's technological leader. However, our leadership is being challenged—in the military area by the Soviet Union, and in the civilian area by Japan. Because technological superiority is a significant part of our military and economic national strategy—it is critically important to maintain our leadership position.[6]

Gansler obviously noted that our continued industrial and technological dominance, on which we base our force structure, was being jeopardized be-

cause many of our strongest and most efficient companies have been crippled in fierce global competition by the cumulative effect of many diverse factors. These include the oil and inflation shocks of the 1970s (with resultant increases in deficits and debts both in the United States and in the South American countries that were a major export market); alleged unfair practices by our trading partners; the high cost of capital as a result of consumer overindulgence and government largesse; and the neglect of quality in production and the concomitant minimal investment in technology required to produce competitive products and to improve productivity.[7]

Attempting to explain the reasons for our "competitiveness" problems, Ian I. Mitroff, distinguished professor of business policy at the University of Southern California, believes the United States is a victim of its own success. Many of the factors that allowed us to dominate the world's economic market now work against us. He cites the following.

> We had cheap, abundant energy, labor, and raw materials that gave us a decisive advantage over most other countries with regard to production and manufacturing capability.
>
> The US had such a huge, unsaturated domestic market that we virtually could ignore the rest of the world. In effect, we didn't have to think globally and develop global marketing strategies.
>
> The theory of comparative advantage . . . seemed immutable. Today, however, virtually any country can import the technology necessary to produce just about anything.
>
> With decreased costs of transportation and raw materials, and the ability to rapidly transmit data, the world has lost its natural buffering of distance between nations.
>
> In the past we could get away with equally huge bureaucratic organizations and production lines that were sloppy or inefficient, and with friction and hostility between labor, management, government, and stockholders. Today we're competing with countries that make quality goods because they've forged close alliances between their employees, managers, governments, and shareholders.[8]

A recent Office of Technology Assessment report confirms that "there have been troubling indicators that the US technological lead is slipping and that it is increasingly difficult to maintain a meaningful lead."[9] Not surprisingly, industries in which the United States is losing or has already lost dominance include such core competitive sectors as automobiles, steel, machine tools, robotics, fiber optics, and semiconductors.[10] Consider that in the mid-1960s the United States controlled 50 percent of the world market for televisions, 90 percent for radios, 76 percent for automobiles, and 47 percent for steel. In 1988 we only control 6 percent of the television and radio markets combined, 28 percent of the automobile market, and 20 percent of the steel market.[11] Our technological leadership has deteriorated to the point where there appears to be only four major industries left in which domestic firms still lead the world: agriculture, aerospace, computers, and pharmaceuticals—and by all accounts, we're rapidly losing ground in each.[12]

Reasons for the Loss of US Technological Leadership

Our industrial/technological base problems run deeper than the loss of competitive capacities in our commercial and defense sectors. In today's rapidly changing environment, a nation's economic and military vitality increasingly relies on its science and technology base—which in turn depends on capable corporate management, a strong labor force and educational system, and a generous investment in research and development.

Corporate Behavior

In an attempt to determine the reasons for our failure to maintain the unquestioned technological lead that we had held for decades, the *Los Angeles Times* and the Booz-Allen & Hamilton management consulting firm surveyed US and Asian business executives.

The survey found that US companies are

> fixated on quick research payoffs, blind to the ability of technology to open new markets, inattentive to the contributions that scientists and engineers can make to corporate success, and out of touch with the innovative power that drove their firms to technological leadership.[13]

The survey also found that as a result of institutionalized procedures, US executives are engaging in short-term, risk-dodging practices that will inevitably lead to further erosion in our leadership position. Such short-term behavior may be a result of past experiences with the high levels of inflation that predominated in the 1970s and required quick returns on investment in order to pay off high-interest loans. Based on that experience, many companies have sought managers with financial skills who naturally push short-term research and development projects over longer-term projects that might result in a technological breakthrough.[14]

Ignoring the advice of experts to adopt a longer time-frame perspective, US firms still engage in such counterproductive short-term practices as formally evaluating key executives at least once a year. Survey responses indicated that 59 percent of the Americans and only 2 percent of the Japanese executives were evaluated that frequently. As inappropriate as such a process may be to cultivating a long-term perspective, surprisingly 45 percent of the American executives found it acceptable—while none of the Japanese executives thought so.[15] Other insightful findings from the survey include the following:

> Developing new technology does not rank as a business priority for American executives. But it is the Japanese manager's second highest goal, behind increased profitability.
>
> The American companies' leading objective in innovation is the development of new products for their existing markets. The Japanese are more ambitious, aiming to create new products for new markets.
>
> Four out of ten US companies extract their profits from investments in technology within three years. The Japanese are giving projects more time to become profitable.

More than 8 in 10 of the Japanese executives are devotees of technology planning processes that link research and development with their company's business plan, but only 50 percent of the American executives find them effective.

Three of four Japanese executives consider it valuable to promote engineers and other technical professionals into top management, but barely one in five US executives value that sort of technical proficiency in high management circles.[16]

Ralph Gomory, senior vice president for science and technology at International Business Machines (IBM), adds that although the United States leads the world in science and technology research, this does not necessarily translate into product sales. He contends that not all product innovations are based on scientific breakthroughs—the US strength. Many more are based on iterative improvements of existing products—Japan's strength. So while the Americans prefer to wait to develop a new product based on the next scientific breakthrough, the Japanese are constantly improving—and selling—existing products.[17]

Ralph Landau, a faculty member at the Kennedy School of Government of Harvard University, believes that "companies in every sector of the economy must adjust to a faster pace of change, insist on continual training, and remove obsolete policies that impose unnecessary constraints on technological innovation."[18]

Shortage of Skilled Craftsmen

Given the specialized nature of advanced technology and its need for skilled workers, the American work force does not appear to be well positioned to meet the challenges of the future. For a variety of reasons ranging from demographic forces to worker disillusionment with repeated layoffs, a serious labor shortage is emerging for skilled blue-collar craftsmen such as machinists and electricians. This shortage of skilled labor in both the defense and civilian sectors jeopardizes the productivity and competitiveness of US industry. Not surprisingly, many of our firms have moved their operations to the newly industrialized countries that have a plentiful supply of capable and lower-wage workers. The national security implications of this situation are of grave concern when one considers that the availability of skilled craftsmen has historically been the most significant constraint to an industrial surge capability during an international crisis.[19]

The demise of our blue-collar skills is not the only concern. Numerous studies have shown that most of the advances achieved in this nation are due to product innovations [illegible] factory during the production processes, not from ac[illegible] laboratory experiments. Therefore, knowledgeable and experienced engineers are crucial for our future competitiveness. However, as a result of "outsourcing" its manufacturing needs to other nations, our increasingly "hollow" corporations are exporting the opportunities necessary to develop the talents of our design and production engineers. Such a practice inevitably leads to lost leadership in key segments of our industrial/technological base.[20]

A prime example of this loss of leadership as a direct result of exporting jobs involves the experiences of Intel Corporation—one of the founders of the nation's semiconductor industry. After Intel had recently built a new assembly plant in Arizona, it could not find any domestic experts to set up the assembly line and had to import the skills from one of its plants in Malaysia. In a matter of a few years it had lost a skill it had pioneered.[21]

Education Shortfall—Particularly in the Sciences

There are certainly many contributing causes to America's failure to maintain its decades-long technological edge over the rest of the world. Marvin L. Goldberger, president of the California Institute of Technology, cites the following fundamental reasons for giving the United States that edge.

- The success of scientific enterprise depends heavily on the contributions of a relatively small number of spectacular individuals.
- The United States had an enormous infusion of foreign talent that fled the various European tyrannies before World War II.
- The United States did not have much competition until very recently because it took Western Europe, the Soviet Union, and Japan a long time to recover from the devastation of World War II.[22]

One can readily assert that our national leadership and educational system has rapidly squandered the technological lead we attained by default after World War II. Primarily, we have failed to develop the nation's young minds—our greatest national asset and the key to our future. The Omnibus Trade and Competitiveness Act of 1988 recognized the alue of education to our nation's future: "The relationship between a strong and vibrant educational system and a healthy national economy is inseparable in an era in which economic growth is dependent on technology."[23]

As the nation faces a declining influx of entry-level workers as a result of the end of the post-World War II baby boom, an educated work force takes on even greater importance. Many jobs in the fast-growing service sectors require more education than those in the shrinking blue-collar sector.[24] In fact, recent estimates show that by 1990, 75 percent of all new jobs will require more than a high school education.[25]

However, despite the obvious need, we have not invested in the educational resources required to develop the labor force we will need to win the international trade challenge. Consider that recent government statistics reveal there are about 21 million functionally illiterate adults in the country. Commenting on this fact, Benita Somerfield, special adviser for adult literacy at the Department of Education, stated,

"We've got a serious problem. And the serious problem is that we don't have the work force we need to do the jobs in the year 2000, and it doesn't really seem as if we have the work force to do the jobs we have right now."[26] Given our trade imbalance with Japan, it surely is no coincidence that while only 70 percent of Americans complete high school, the graduation rate for Japan is 90 percent.[27]

Beyond the basic issue of functional illiteracy, the precollege quality and quantity of science and mathematics has been decimated by a shortage of qualified teachers—primarily because of the exodus of women from the profession for higher-paying positions in industry. The consequences of our disregard for a sound academic foundation in these critical competitive disciplines are ominous. Results of a recent international mathematics test administered to high school seniors in 11 industrialized nations had the United States in tenth place—while Japan finished first.[28] Furthermore, a recent survey by the National Teachers Association of 24,000 high schools throughout the nation revealed that 7,000 offered *no* physics courses and 4,000 offered *no* chemistry courses.[29]

The results of our past educational failures are also visible at the highest levels of our educational system. Many studies have documented that American universities are awarding a rising percentage of their hard science doctorates to foreign students. Of the engineering doctorates awarded in 1986, 60 percent went to students who were not US citizens. Similarly, foreigners earned 40 percent of the mathematics and computer science doctorates in 1986.[30] This trend is increasingly being noticed in our work force. As it currently stands, one-third of American industry's engineering doctorates are held by foreign-born individuals. At the Massachusetts Institute of Technology (MIT), one of our nation's preeminent engineering schools, 2? percent of the total student body are foreign nationals.[31] Further, in 1985, 45 percent of the engineering graduate students in the United States were foreigners studying here on temporary visas, while another 10 percent were noncitizens with permanent-resident visas.[32]

Erich Bloch, director of the National Science Foundation (NSF), also takes a critical view of our educational posture:

> While Americans take degrees in law and business, foreigners are taking their place at the Ph.D level in science. We're lucky to have them. A significant number remain in the US, or go to work for American companies abroad. But as opportunities overseas increase, we may find that the numbers of foreign students coming to our universities decline.[33]

Even if the foreign-born engineers remain in the United States, their rising proportion in the work force is reducing the pool of highly trained engineers available to work in federal laboratories and defense contractors on national security-related projects since government security regulations exclude noncitizens from most defense-related jobs. Further, a recent National Academy of Engineering study contends that the presence of a large number of foreign faculty members in our engineering schools is hampering relations between universities and the government's national laboratories that are devoted to weapons research and other national security studies.[34]

To summarize, a 1983 Office of Technology Assessment study reported that "the overall technical edge of the nation has diminished. In particular, research capabilities in American Universities have deteriorated because of obsolete equipment and shortages of graduate students and faculty."[35] Richard S. Morse, former assistant secretary of the Army for research and development and a former faculty member at MIT, has a harsh view of our nation's future:

> Until the quality of science and engineering education are upgraded at all levels of American society, and until the directors of America's industry assume the responsibility and obligations of their job and demand that CEOs [chief executive officers] have the characteristics needed to operate in a changing technological society, American companies will not be competitive in the changing world marketplace.[36]

Impact on DOD

As a nation, our \$17-billion trade surplus in 1980 fell to a \$167-billion deficit in 1987.[37] Notwithstanding who or what is to blame for the decline of our economic leadership, these figures underline the fact that many key industries essential to our national security have encountered serious problems as a result of global competition. Not only are our core heavy manufacturing industries under siege from foreign imports, but so are our high-technology industries—the basis for our future economic and military strength. Consider that after posting a \$27-billion surplus in high-tech trade as recently as 1980, the high-tech sector reported its first trade deficit in 1986.[38] If this trend is not reversed, DOD will soon find itself heavily dependent on foreign sources for many of the items needed to maintain the "qualitative" edge.

To appreciate the criticality of the problem, consider the following facts:

- A small German plant located 30 miles from the Czechoslovakian border produces all the high-purity silicon necessary to manufacture the chips used in many of our missile-guidance systems. Destruction of this plant would cripple our ability to resupply allied forces.[39]
- Modern tanks, aircraft, and other defense products use mass-produced metal parts that require highly precise machining. Yet, in 1986 foreign companies captured 49 percent of the US machine tool market, up from 25 percent five years earlier. During the same period, the number of domestic machine tool plants shrank by one-third and the employment of skilled craftsmen plunged 28 percent.[40]
- In the heavy equipment industry, the Caterpillar Tractor Company, the largest single customer of the US forging industry, has increased offshore purchases of

components by 400 percent since 1981 in order to survive in today's highly competitive world market. As a result of this and similar actions, the domestic forging industry has experienced a 40-percent market loss and a commensurate loss of its skilled work force between 1981 and 1987.[41]

• Bearings are used for a variety of products, from huge swivels for mounting construction cranes to miniature bearings for computer disk drives. This industry lost about 15,000 jobs between 1980 and 1987. Additionally, about 65 percent of US ball bearings and roller bearings are now imported from overseas.[42] DOD is particularly concerned about this situation because imports account for 90 to 95 percent of the specialty bearings it uses—including noise-free, high-precision bearings used for Trident submarines and other strategic weapons.[43]

• Ten years ago, the US industrial base produced 90 percent of all power shovels used by the domestic mining industry. In 1987 only about 10 percent were manufactured domestically.[44]

• The US plastics industry, which supplies injection molding machinery for such critical defense products as shell casings, submarine-detecting sonobuoys, and submarine/missile/jet engine parts, claims foreign manufacturers account for two-thirds of domestic injection molding machine sales.[45]

• The polyacrylonitrile (PAN)-based carbon fiber industry, which produces the high-strength and lightweight composites increasingly used in advanced technology aircraft, is totally dependent on foreign sources. Defense requirements for this product are likely to increase dramatically in the next few years.[46]

• Forty percent of the electronics in US weapon systems come from Japan. Analysts estimate that this will increase to 50 percent by the early 1990s.[47]

• Seventy-five percent of the precision optics used by DOD for such critical applications as space surveillance and overhead reconnaissance come from Japanese and other Asian sources.[48]

The Boeing Example

Our nation's commercial high-tech firms have been widely criticized for their inability or unwillingness to react to the challenge of foreign competition. As early as 1983, some of our key national leaders sounded a warning that was apparently ignored. A panel of business executives, university scholars, and public officials, headed by Howard W. Johnson—chairman of MIT—testified before the Senate Finance Committee on the results of a study they had just completed. Their major concern was that "the American public is unaware of the importance of high-tech to the country's well-being and that other industrialized nations such as Japan and France will assume preeminence before the United States wakes up to the problem." [49]

The seriousness of the challenge can be readily appreciated if we consider the competitive status of one of the nation's best corporations—the Boeing Company. Boeing, the world's largest maker of airliners and the eighth largest US defense contractor, is facing intense competition from Airbus Industrie, the European consortium. After winning nearly 80 percent of the worldwide commercial sales during 1980 (while Airbus won only 10 percent), Boeing's share plummeted to 49 percent during 1987 while Airbus's share rose to 26 percent.[50]

Unless the depreciated dollar severely constrains Airbus's strategy, the outlook for Boeing's future appears bleak. Airbus has about 300 firm orders for its newest jet, the 150-seat A-320 developed to beat out the Boeing 7J7 propfan—a plane still on the drawing boards—and one for which Boeing has no orders. In fact, due to recent financial constraints associated with the estimated $4-billion 7J7 development, the project has been postponed indefinitely so that Boeing can concentrate its resources on the current Airbus challenge. In addition to delaying the 7J7 program, Boeing has decided to pass on plans to vertically integrate its military business through big acquisitions in order to maintain liquidity during its battle with Airbus. To make matters worse, Airbus is currently designing a wide-body airframe to challenge the industry's dominant model, the Boeing 747.[51]

When the company determined it was not making the profits necessary to finance the next decade's aircraft development, Boeing began urging the US government to threaten trade sanctions if France, Britain, Spain, and West Germany refuse to end their estimated $3-million-per-plane production subsidies—which are in addition to their subsidization of billions of dollars in development costs.[52]

The resolution of this issue will not be easy. Europeans often point out that, as a defense contractor, Boeing has received billions of dollars for defense-related R&D, some of which surely is applicable to its commercial business. Further how does one treat the different tax structures among the various nations. All in all, there is a lot more to the subsidy issue than meets the eye.

Nevertheless, Boeing appears to be in trouble. Its concern is surely not an idle cry of "wolf" from an inefficient firm. Consider that in *Fortune* magazine's 1987 survey of corporate performance, Boeing finished third on the overall list of 300 diverse companies—and first among aerospace firms. Rankings were based on such measures as quality and innovativeness.[53]

Boeing's prospects in the face of the Airbus challenge are uncertain, for

> unlike US automakers when they first became serious about Japanese competition, Boeing isn't grossly overstaffed or mismanaged, and its products have a reputation for quality. Because the company already employs state-of-the-art production processes, shaving costs could be tough.[54]

The *Wall Street Journal* sees the battle as a prime test of the ability of American firms to compete against

government subsidized rivals around the world. Given our huge trade deficit, this particular challenge has significant national importance. In 1987 Boeing was the nation's largest exporting company, with $15.8 billion in international orders on its books. Consider that without its $6.5 billion in foreign sales in 1986, the nation's $156-billion trade deficit would have been 4 percent higher.[55]

Technology Transfer, Offsets, and Future Competitiveness

As early as 1972, Randolph Myers of the Transportation Equipment Division of the US Department of Commerce foresaw the competition discussed above. He recognized that skyrocketing development costs were exceeding the ability of even the largest and healthiest commercial aerospace firms to finance. Since the major airframe and engine manufacturers had invested heavily for their then-current product line, they could not undertake new projects to meet foreign competition head-on until they had recouped their development costs.[56]

Ironically, domestic firms were forced to seek financial assistance from government-subsidized foreign aerospace firms. The resultant joint programs were desperate attempts by our domestic firms to maintain their market shares. However, as many of our firms soon discovered, foreign funding assistance comes at a high price. In return for financial help in the development of a commercial project, domestic firms are usually required to transfer to the foreign "partner" such critical aerospace technologies as advanced manufacturing techniques, composite materials, powder metallurgy, and sophisticated electronics.Consequently, these "devil's pact" agreements only hasten the day when subsidized foreign companies can match or exceed the best US technologies at lower prices.[57]

Such seemingly myopic behavior is not limited to the commercial sector. A more ominous scenario involves the Air Force's F-15 program. In 1976 DOD authorized an agreement between McDonnell Douglas and Japan authorizing Mitsubishi to build 179 F-15s, while requiring that Japan buy only eight aircraft made in the United States.[58] In large part due to the transfer of F-15 production know-how, Mitsubishi now has the expertise required to serve as the prime contractor on Japan's FSX advanced fighter program. The Japanese intend to extensively modify and upgrade F-16 airframes with their own advanced avionics and fire control systems. Once this advanced aircraft rolls off the production line in the 1990s, it will be interesting to see if the Japanese will market it to other nations in competition with the United States.

While a recent Office of Technology Assessment report found that "the import of foreign technology has been a central element of Japanese economic development since the late 19th century,"[59] arms transfers to foreign nations had been an important part of our industrial base strategy for the past 15 years. On the positive side, increased sales of American weapon systems have effectively reduced the unit price of each system bought by DOD for US forces. These sales have also kept domestic assembly lines "warm" and a portion of the associated skilled labor force and subcontractors available and viable until the next big order comes down the pipeline. Additionally, sales to our allies also help overall warfighting capabilities through weapons standardization.

However, the arms export business has undergone a significant transformation over the past 20 years. In 1969 the United States controlled 60 percent of the arms export market. Then, mostly as a result of Middle East tensions in the 1970s, arms sales grew at an average rate of 7 percent per year.[60] Recognizing significant profit opportunities, new countries entered the arms export business, thus dramatically increasing supplies and competition. Then, with the worldwide recession and the drop in oil revenues during the early 1980s, the competition for arms sales became fierce. By 1984 the US share of the arms export market had fallen to 22 percent.[61] (However, it should be noted that arms trade with the North Atlantic Treaty Organization (NATO) remained at a favorable 1.6:1 ratio in fiscal year 1986, producing a $1.7-billion surplus. Further, sales to South Korea and Japan were about a 4:1 ratio—producing a $560-million trade surplus.)[62]

As the intense competitive pressure surrounding the arms export business grew, many purchasing nations found themselves in a buyer's market and began to demand offsets as a precondition of sale. Offsets are a required form of nonmonetary compensation agreed to by the seller in return for obtaining the contract. They can be either direct or indirect. Direct offsets are those related to the specific contract and the specific product under consideration in the purchase. Moreover, they usually involve the transfer of technology from the seller to the buyer. For example, the seller may license the buyer to produce certain components of a system for incorporation into the end product. This is a frequent practice among developed countries on large aircraft purchases. Indirect offsets involve goods or services unrelated to the basic transaction, such as agricultural commodities, investment arrangements, manufactured goods, or other items.[63]

A common offset arrangement requires the arms producer to subcontract certain work within the purchaser's country. Such subcontracts are not always limited to work associated with the weapon system being purchased and often involve subcontracting opportunities on other projects. Thus, while prime contractors continue to receive contracts and fulfill them for a profit, the work being transferred overseas as a defense offset is often work that used to be handled by a US subcontractor—often in an ailing strategic industry.

Over the past 15 years, offset arrangements have grown significantly. Only 15 countries had offset requirements in 1972, but the number had risen to 88 by 1984. More important, it has been estimated that offsets accounted for between 20 and 30 percent of the $2 trillion of total world trade in 1983.[64]

Even though the "two-edged sword" characteristics of offsets was officially recognized as an issue in 1984 in an Air Force Aeronautical Systems Division report titled *Blueprint for Tomorrow*,[65] the government has maintained a "hands-off" policy toward the offset problem. Other than reviewing and authorizing a specific sale under the Arms Export Control Act, the government has not been involved in offset negotiations since 1978. In fact, even though DOD and the Departments of State, Treasury, and Commerce—along with the Office of the United States Trade Representative—have vested (and often conflicting) interests in offsets, no government agency monitors or controls offsets.[66]

Despite the fact that arms sales containing offsets are profitable to the American companies involved, are probably necessary to win the contract, and may lead to additional orders from other allied nations, many interested parties are viewing the practice with increased skepticism. The primary long-term concern is the transfer of technology discussed above, which turns foreign customers into competitors. Such transfers have obviously helped foreign producers to leapfrog costly and lengthy developmental stages, thus jeopardizing the domestic industry's opportunity to stay one step ahead of the competition.

The significance of the offset issue can be appreciated when one considers that between 1980 and 1984, $22 billion in US defense sales to other nations generated $12 billion in offset commitments.[67] In the extraordinary cases of sales of aircraft warning and control system (AWACS) aircraft to Britain and France, Boeing agreed to offsets worth 130 percent of the value of each contract.[68] As stated above, although such sales increase standardization and do not cause the prime contractor competitive damage in the short run, they have an immediate adverse impact on the subcontractor segment of our domestic base. For example, in its offset arrangement in the sale of F-5s to Switzerland during the mid-1970s, Northrop Corporation agreed to help the Swiss sell $43 million of machine tools in the United States, to the detriment of our weakening machine tool industrial base.[69]

To summarize, critics increasingly complain about the work lost to foreign subcontractors. These losses are exacerbated by American technology transfers and by what amounts to direct promotion of imports by US defense firms. Among the domestic companies most often injured by such offset arrangements are the already ailing machine tool, precision ball bearing, and optical technology segments of our industrial base.[70] It is not surprising that years after the offset agreements have been executed, DOD must implement protectionist procurement policies in an attempt to "rescue" decimated second-tier industries.

Export Control Roadblocks

Not all of our industry's competitiveness problems are self-inflicted. In some cases involving technology transfer, it appears that DOD has adversely impacted our domestic industry's long-term prospects while purportedly looking out for the national interest. Although it is indisputable that the competitiveness of our high-tech industries is critical to our national security, the government's control of commercial product exports can endanger the continued viability of those very same industries that provide DOD with its dual-use (civilian and military) products.

The primary allied effort to keep strategic resources out of the Communist bloc is accomplished through adherence to the guidance established by the Coordinating Committee on Multilateral Export Control (COCOM), which is comprised of Japan and all the NATO nations—excluding Iceland. The primary document for controlling resource transfer is called the "Paris list" and is comprised of distinct categories of sensitive technologies. These categories are sensitive nuclear-related technology, munitions, and dual-use technologies. It is the dual-use category that has caused the most concern among businessmen and our allies. Both groups believe the list is too broad in its scope and too restrictive in its application. Interestingly, the list is drawn up by the Institute of Defense Analysis without input from industry, the intelligence agencies, or the defense services.[71]

In addition to the Paris list, the COCOM agreement authorizes each member nation to unilaterally impose additional export restrictions on its domestic industry. Consequently, through the auspices of the Bureau of Export Administration (within the Department of Commerce), the United States has added numerous additional dual-use items to the core list to further constrain sales by domestic firms. These additions exacerbate monitoring difficulties because the line between military and civilian products is becoming increasingly vague as the potential uses of new products keep changing. These complications induce delays in keeping the guidance up to date, with the result that US firms are prohibited from marketing products that other COCOM nations are free to sell to anyone.

A strong case can be made that rather than increase national security, such overzealous export restrictions actually weaken our overall position. A 1985 report by Georgetown University's Center for Strategic and International Studies found that "to the extent that export controls result in lost revenue needed by US exporters and multinationals to invest in future generations of technology, they in all likelihood retard military innovation originating in the civilian sector."[72] The report cited numerous technologies such as semicon-

ductors, communication networks, lasers, and robotics that "have been derived from civilian research and development, and have created commercial applications and markets far exceeding in diversity and size their military counterparts."[73]

Although export controls are supposed to be lifted on items that can be proven to be readily available from non-COCOM nations, this usually does not occur. A 1988 National Academy of Sciences report concludes that the availability of such items has had virtually no impact on easing export controls.[74] Commenting on the COCOM list, late Secretary of Commerce Malcolm Baldrige estimated that it was too broad by 30 to 40 percent.[75] In fact, "higher walls around fewer items" has become a rallying cry for those seeking to protect truly vital technology without having to resort to blanket controls. As an indication of how burdensome and overwhelming export controls can be, a review of Commerce Department export data for 1985 indicated that almost 40 percent ($62 billion) of all nonmilitary manufactured goods required prior approval by the government.[76]

As stated in the Georgetown University report, "The trade-off between the risk of losing superior US technologies to the Soviets and the risk of losing sales to competitors in foreign commercial markets is at the center of the debate over US export control policy."[77] In order to get a better grasp on the broader control issue, a 1987 National Academy of Sciences study was chartered to review the effects of export controls on commercial high-technology trade and on the US high-technology industry. The study members included former US Air Force Chief of Staff Gen Lew Allen, Jr., USAF, Retired; former deputy director of the Central Intelligence Agency Adm Bobby Inman, USN, Retired; and former Secretary of Defense Melvin R. Laird. Their report, which is often called the "Allen report," noted a weakness in current US technology export control practices and the inhibiting effects of these practices on US global economic competition. They found that as the United States works to reduce its trade deficit and recapture overseas markets, export restrictions amount to a self-imposed trade barrier the nation can scarcely afford. The panel recommended a "restoration of technical judgment and balance to the national security export licensing process."[78]

A prime example of the counterproductive nature of certain government controls involves the recent experiences of the industry providing earth imagery from satellites. In 1978 a presidential directive set a 10-meter resolution limit on commercial remote-sensing satellites that provide high-resolution photographs to commercial customers. A 1987 National Oceanographic and Atmospheric Administration (NOAA) regulation empowered the State and Defense Departments to veto potential sales of high-resolution satellite systems considered to be threatening to US national security.[79] The government (primarily DOD) was concerned that technological progress would soon provide the capability to acquire high-resolution (less than 10 meters) photographs that could compromise sensitive national security data. Although such a concern was understandable, critics noted that such regulations would relegate the domestic commercial satellite imagery industry to that of a second-rate competitor as other nations passed it by with more advanced systems. As a result of the 10-meter resolution limitation, the domestic commercial satellite sector was naturally unwilling to expend millions of dollars to develop systems they could not market. So while the government was restricting the activities of our domestic firms, our international competitors (military and economic) were fully committed to developing such satellites. Within a year of the most recent Department of Commerce reaffirmation of the 10-meter restriction, the Soviet Union was freely marketing satellite photographs with a resolution of five meters. Only after finding itself in the embarrassing position of having some of its own agencies trying to buy photographs from the Soviets did the United States move to rescind the controls. The "new" government position is to "encourage the development of US commercial systems competitive with or superior to foreign-operated civil or commercial systems."[80]

Similarly, GCA Corporation used to be one of the world's leaders in producing wafer stepper machines used in the manufacture of semiconductors. However, as economist George Gilder recounts, "Right at the moment that Nikon and Canon entered the market and Asia became the world's fastest growing semiconductor area, GCA was prohibited from selling overseas for national security reasons."[81] As a result, GCA lost significant revenues that surely could have helped it ride out the worldwide semiconductor slump in the mid-1980s. Without the required capital cushion, GCA came within one day of filing for Chapter 11 bankruptcy protection on several occasions.[82] The Japanese firms are now the unrivaled world leaders in this strategic technology, while GCA struggles to retain its solvency.

Export control policy appears to rely on the faulty assumption that the United States has a monopoly on advanced technology and that by closing its doors it can keep the rest of the world from advancing technologically. While this may have been true to some extent immediately after World War II, it surely is not the case today. The main point of the examples cited above is to demonstrate that our bureaucratic process is unable to recognize when technology has made certain export controls moot and to show that the imposition of, and adherence to, such controls is counterproductive to the continued viability of our technological base. The language of the Export Administration Act of 1979 requires that the United States resort to "use of export controls only after full consideration of the impact on the economy. . . ."[83] Obviously, this has not been the case.

Recognizing the danger of overbearing government controls, Commerce Secretary Baldrige had noted that "national security is comprised of both economic and military security."[84] Under Secretary of Commerce for Trade Administration Paul Freedenberg expanded upon this view by stating:

> US national security requires that American companies must be healthy. . . . We must not, therefore, continue to bite the hand that feeds us. . . . We must stop subjecting to over-control the very same private sector companies upon which we rely to keep us technologically superior to our adversaries. We must limit the role of government to doing only what is truly necessary to protect national security. And then, at that point, government should get out of the way and let American business go about its business of selling quality products at competitive prices.[85]

The previously mentioned Allen report estimated that the losses in gross national product (GNP) associated with US export controls were approximately $17 billion in 1985. Although the report does acknowledge the importance of export controls over critical defense products, the panel could only document "rare" instances where dual-use (commercial and military) technology contributed substantially to Soviet military developments.[86]

In 1987 American officials learned that between 1981 and 1984 a subsidiary of the Toshiba Corporation had sold to the Soviet Union some state-of-the-art machinery that could be used to mill ultraquiet propellers for submarines. At the same time, the Norwegian company of Kongsberg Vaapenfabrikk had sold the Soviets a computer control system for operating the Toshiba equipment. Both transactions violated an agreement limiting high-tech sales to the Soviet bloc. While the United States must ensure that there is not a repeat of the Toshiba-Kongsberg incident, a sense of balance must certainly become a part of our export control policy. Marshall I. Goldman, professor of economics at Wellesley College and associate director of the Russian Research Center at Harvard University, believes that

> while corporate greed is a major cause of [export] violations, so too is the US tendency, encouraged by the Pentagon, to over-regulate trade with the Soviet Union and Eastern Europe. That practice breeds wide-spread, and well-founded, cynicism and disregard for controls. . . . There are lessons to be learned from . . . Toshiba and Kongsberg. . . . Hard as it may be, it is necessary to prune continually the lists of what is strategically sensitive. What is exotic and strategically important today is likely to be mundane and easily accessible tomorrow. By all means the United States should deprive the Soviet Union of this nation's most important military technologies, but the rest should be deregulated. That way regulators can concentrate on what is essential. What good is it if we so distract ourselves with those who run red lights that we ignore armed robbers?[87]

Impact of DOD's Research and Development Expenditures

Even though former President Ronald Reagan acclaimed that "science and technology are fundamental to US competitiveness [and that] America's preeminence in science and technology has long been the envy of the world and a critical source of our national strength," funding for basic research has declined precipitously during the past few years.[88]

In fiscal year 1988, defense accounted for 72 percent of government research and development funding, up from 51 percent in 1980.[89] Although past development of certain technologies had been accelerated by DOD-sponsored R&D (e.g., computers, jet engines, and integrated circuits), military technology has become increasingly specialized with a decreased emphasis on basic research. A recent Rand Corporation paper supports the view that today most defense R&D expenditures go toward weapon systems that have little commercial application and no longer have the much-acclaimed "spin-off" benefits that advocates proclaim.[90] In fact, during the last 30 years, only 5 percent of the government's 28,000 patented inventions have been licensed for commercial use.[91]

For decades, at least 30 percent of our nation's engineers and scientists has been drawn into military research and development. Many observers believe this diversion of technologies has overwhelmed whatever spin-off occurred, slowed technological progress, and undermined industry's ability to offset higher wages and other costs with increased productivity.[92] David Packard, cofounder of Hewlett-Packard and a former deputy secretary of defense, contends that

> this [Reagan] administration pushed for a big buildup in defense expenditures, and today the Pentagon is utilizing a large proportion of the scientific and engineering talent in the country. But it *is not paying* its fair share of the [opportunity] cost of those scientists. This is not only shortsighted, it is very stupid.[93]

While George A. Keyworth II, former science adviser to President Reagan, believes that much of DOD's R&D does have application in both the civilian and military sectors, he does acknowledge that the nation has done a poor job of taking advantage of DOD's discoveries. He attributes most of the technology transfusion problems to DOD obstructionism—motivated by overzealous concern about technology transfer to the Soviets.[94] Although the federal laboratories and the Strategic Defense Initiative (SDI) program office have recently undertaken initiatives to facilitate technology-sharing with industry, most defense technology advances that may have commercial applications are classified, while raw basic research data is often not practical for commercial development.[95]

It should be noted that SDI may be an exception to the general argument that military-related R&D does not have a great commercial spin-off value. SDI advocates project numerous spin-offs in such diverse areas as biomedical applications; electronics; communications; power generation, transmission, and storage; materials and industrial process applications; and computers. In fact, Wolfgang Demisch, one of Wall Street's preeminent defense sector analysts, speculates that "the actual economic effect of SDI spin-offs will be that SDI will pay for itself."[96] However, William Bridges,

professor of engineering at the California Institute of Technology, contends that "there are much better ways at much lower costs to pursue the [civilian] R&D specified in the SDI program."[97]

Regardless of the outcome of SDI spin-offs, Erich Bloch of the National Science Foundation believes that "we should be asking ourselves how much fallout there is from civilian basic research to the defense sector. There's a hell of a lot more in that direction. That wasn't true 20 to 30 years ago, but it is today."[98] Hidehiro Konno, the director of Japan's Ministry of International Trade and Industry (MITI) aircraft and ordnance division, asserts that although military technology once spun off into civilian uses, the flow is now reversed as civilian technology increasingly feeds modern military arsenals. For example, initially carbon fiber composites were so expensive that their use was limited to such high-price applications as military airframes. But when Japan's commercial sector perfected the manufacturing process for this material, it became cost-effective for use in such day-to-day commercial applications as golf clubs and fishing rods. Similarly, the electro-optics used in missile-guidance systems are essentially the same technology as first developed for home video cameras.[99] Also note that all the national security ramifications of the Toshiba-Kongsberg incident concerned a *commercial* milling machine.

In his advocacy for more basic R&D (which amounts to slightly more than 2 percent of DOD's R&D funding),[100] Gen Robert T. Marsh, USAF, Retired, a former commander of the Air Force Systems Command, is especially critical of the funding drain caused by SDI research. In light of the Gramm-Rudman-Hollings deficit reduction package he says that

> the decision to protect SDI in the R&D budget means that the other defense R&D programs—including the technology base—must take especially hard hits . . . the emphasis on SDI also influences the availability of resources for other research efforts. Scientists and engineers, colleges and universities, and industry make decisions about in-house research based partly on their assessment of available DOD funding. When SDI-related research money predominates, we can anticipate missed opportunities in other areas.[101]

For example, when SDI was initially launched in 1983, DOD had to cut back certain projects in order to fund the program. One of the projects affected was the Defense Advanced Research Project Agency's (DARPA) Strategic Computing Initiative, which was our response to Japan's effort to build fifth-generation computers that will operate using artificial intelligence.[102] Such DOD action was predictable since applications with direct relevance to defense objectives are naturally favored over longer-term basic projects with only indirect (but sometimes vital) military benefits.

While the United States continues to spend the bulk of its federal R&D funding on military applications, our largest economic rival, Japan, commits only 2 percent of its national R&D budget to military applications.[103] Since the Japanese and other US trade rivals do not have comparable defense burdens, their R&D expenditures are devoted mainly toward commercial product and process development in such high-potential areas as biotechnology, artificial intelligence, automatic language translators, robotics, and superconductivity.[104]

Paul Kennedy, the J. Richardson Dilworth professor of history at Yale University, contends that

> if the United States continues to direct a huge proportion of its research and development activities toward military-related production while the Japanese and West Germans concentrate on commercial research and development, and if the Pentagon drains off the ablest of the country's scientists and engineers from the design and production of goods for the world market, while similar personnel in other countries are bringing out better consumer products, then it seems inevitable that the American share of world manufacturing will decline steadily, and likely that American growth rates will be slower than those of countries dedicated to the marketplace and less eager to channel resources into defense. . . . A small investment in armaments [and armament research] may have a globally overstretched power like the United States feeling vulnerable everywhere, but a heavy investment in them, while bringing greater security in the short term, may so erode the commercial competitiveness of the American economy that the nation will be less secure in the long run.[105]

In addition to government reductions in nonmilitary research and development funding, the commercial sector has not carried its share of the required R&D investment. For example, a recent study by the National Academy of Engineering on aerospace materials discovered that one Japanese steel company alone has almost as many engineers (700) dedicated to advanced research on composite materials as the entire US steel industry (763).[106] Not surprisingly, another study by the National Research Council concluded that Japan has the lead in several emerging technologies that are the key to future electronic and optical device dominance.[107]

The Taxpayer's Perspective

Harry G. Gelber—a renowned expert on strategic and foreign policy matters who has been a visiting fellow or professor at Harvard, Yale, George Washington, Oxford, and Cambridge universities and the London School of Economics—contends that "throughout the modern era, there has been a close connection between economic and military power. Indeed, it is often asserted that military power is directly dependent upon industrial strength."[108] Based on this premise, our nation's current economic problems put the future health of DOD in grave doubt.

Recently, widely respected publications have devoted their cover stories to the questions "Can America Compete?" (*Business Week*, April 1987) and "Why Can't America Compete?" (*Business Month*, March 1987). Not only is the business community concerned, but so is John Q. Public. The following are some of the reasons for this concern:

In the 1960s, a four percent rise in GNP was considered to be the norm. For the average worker, hourly wage raises of close to two percent (after inflation) came easily because the economy was booming and productivity gains were consistently strong. The US was virtually unchallenged as the industrial leader. Somewhere around 1973 things took a turn for the worse. The winding down of the war in Vietnam; the OPEC price shock; the resultant inflation spiral; fierce competition from foreign industries that churned out high-quality goods made by low-wage workers all combined to slow productivity and economic growth. Even though the typical worker's wages continued to soar, it was all negated by inflation. In real terms, he took a pay cut. By the end of 1986 his real wages were back to their 1969 level.[109]

The overall economic climate is important because in the post-World War II era Americans have been willing to support large and expensive standing peacetime armed forces. However, that consensus may soon dissipate as Americans perceive that their real incomes are declining and their ability to maintain the

middle class dream through demographic adjustments—two earner couples, postponed marriages/child-bearing, and low birth rates—will soon become untenable. If the nation does not return to the healthy economy with rising real wages, the middle class, and with it the nation's social fabric, will come under increasing strain.[110]

Also coming under increasing strain will be the willingness of the people to support a high level of spending on national defense. In fact, today many Americans believe that their prosperity is being endangered by the very nations we help to defend—the same ones we must now borrow from in order to be able to afford that protection. Wolfgang Demisch places the situation in a unique perspective:

Things are out of whack. The crumbling dollar says that we, the world's No. 2 economy, cannot go on . . . defend[ing] the world's No. 1 economy (the European Community)—and for that matter, the No. 3 economy (Japan)—from the No. 4 economy (the Soviet Union).[111]

While public opinion is certainly not the most effective mechanism for setting national security policy, a democratic society cannot ignore the voice of the people. Consider that a recent survey by the political polling firm of Marttila & Kiley presented the following findings:

Seventy-two percent of Americans consider the nation's trade imbalance a serious national-security problem.

Fifty-seven percent believed that our economic competitors would pose a greater threat to our national security than military competitors.

Sixty-two percent believed economic power was a more important factor than military power in determining a country's influence in the world today.[112]

Further, according to a Gallup poll taken for the Chicago Council on Foreign Relations, 78 percent of Americans believe that the main aim of our foreign policy should not be to police the seas or to fight communism but to secure American jobs.[113]

Peter G. Peterson, a former secretary of commerce, notes that "eight years ago, no one imagined an austerity-led shift toward US isolationism."[114] Given the massive trade and budget deficits facing the nation today, and the apparent lack of a educational foundation for a dramatic turnaround, the fact that DOD's budget as a percentage of GNP is low by historical standards will not likely save it from devastating cuts in the future.

In summary, our national security has been derived from the will of our people to use our economic wealth to protect the freedom of our nation and our allies. In turn, our financial strength has been derived from our economic system, which is increasingly facing intense foreign competition. Today the situation is such that not only are our core blue-collar industries eroding but so are our high-tech bastions—the ones that have provided the technological edge on which our military strength and deterrence posture are based.

Consequently, DOD has a vested interest in a strong economy comprised of strong industries, many of which are vital to our national security. Of special concern is the fact that DOD has become increasingly more dependent on the commercial high-technology sector to drive many of our most strategic military capabilities. More than ever before, any failure to maintain the commercial technology lead threatens our economic and military strength. DOD must therefore ensure that its acquisition policies consider the long view and do not unwittingly contribute to the demise of industries on which our ability to maintain national security is predicated. We must ensure that our utilization of the nation's assets reflect the best use of those increasingly scarce resources.

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Chapter 2

Recent Government Initiatives to Help Endangered Industries

The secretary of defense's fiscal year 1988 report to Congress confirms the existence of serious deficiencies in the ability of our domestic base to meet DOD's present and future production requirements. It states that, largely as a result of foreign competition, many "basic industries important to defense production have declined," thus jeopardizing the nation's ability to retain the "technical expertise necessary for our long-term economic survival."[1] Former Secretary Caspar W. Weinberger pledged that "where we find that overseas sourcing and dependency are diminishing US industrial preparedness, we are examining innovative ways to make critical industrial sectors more competitive, and less vulnerable to trade disruptions."[2]

The Initiatives

Early in fiscal year 1988, the Office of the Secretary of Defense (OSD) announced the creation of a Trade and Defense Cooperation Advocate position. The advocate is tasked with working against protectionist legislation while working toward an equitable trade policy that will enable industries critical to defense and the economic well-being of the nation to compete and survive as reliable sources of supply. Other major government initiatives are identified below.

Semiconductor Industry

The relationship between DOD and the semiconductor industry has changed dramatically over the years. In 1960 DOD was the industry's most important customer, accounting for about one-half of all production.[3] Today, although DOD only consumes about 10 percent of the country's semiconductor output,[4] the industry remains extremely important to national defense because the custom chips that DOD procures are a vital part of most of today's complex weapon systems. While DOD does not generally purchase standard commercial chips, the iterative development and manufacture of such chips in large volume serves as a "technology driver" and thereby increases industry's knowledge base and enables it to provide improved customized chips for defense and other applications. Therefore, even if the custom chip sector of the industry appears healthy, any weakness in the commercial standardized-chip sector will soon "ripple" through and have a long-term debilitating impact on the industry's ability to provide state-of-the-art custom chips to DOD.

Until the mid-1970s, there was little cause for concern as the US semiconductor industry virtually held a monopoly on the world's semiconductor output. However, in an attempt to break our dominance, Japan's Ministry of International Trade and Industry (MITI) rallied Japanese electronics giants to combine their efforts in a drive for superiority in the high-volume standardized microchip market (primarily dynamic random access memory [DRAM] chips) as a means of strengthening that country's entire electronics industry. The targeting of DRAM chips was critical because they are the "technology driver" of the semiconductor industry. So, while Japan's top firms pooled their research capabilities, its government protected the home market from US competition through a combination of import quotas and restrictions on foreign investments within Japan.[5] Later, as the Japanese firms began to compete directly against the US industry, they took the long-term view and reinvested 35 percent of their revenues in new plants and equipment between 1977 and 1985—while US firms reinvested only 20 percent.[6] As a result of their pooled research, protected home market, aggressive marketing, and high levels of reinvestment, Japan captured 80 percent of the world market for DRAM chips by 1988.[7]

Japan's entry into the market and the worldwide semiconductor slump of 1985–86 were devastating for the US industry. Even though the overall demand for chips was shrinking by 10 percent during this period, Japanese firms continued producing record numbers of semiconductors.[8] Although some people may have considered this practice suicidal, the Japanese were simply acting consistent with their long-term objective of capturing a majority of the worldwide market. Short-term losses were not an issue because the financial resources of their controlling conglomerates enabled them to look beyond the temporary slump in demand.

On the other hand, the much smaller US semiconductor firms typically operated on a much shorter time perspective and did not have the financial resources to endure the slump. Consequently, as the Japanese-in-

duced glut of DRAM chips on the market depressed prices worldwide, only Texas Instruments and Micron Technology Incorporated survived the shakeout among market suppliers in the United States. Besides these two survivors, the only other US DRAM chip manufacturers were IBM and American Telephone and Telegraph (AT&T)—which only produced chips for their own use, not for resale to other firms. Though AT&T weathered the 1985-86 downturn, it also decided to quit the DRAM business in 1987.

It is interesting to note that during the time that the United States was losing its technological leadership in this industry, we were *outspending* Japan in semiconductor research and development. However, while the US government was funding relatively specific R&D for narrow military and other government agency needs, the Japanese government was funding broader programs with commercial objectives. As with other contemporary defense-related R&D, there is little commercial spin-off associated with military semiconductor R&D—as evidenced by DOD's experience on the very high speed integrated circuit (VHSIC) program. Thus while defense contractors received the bulk of the US government's semiconductor R&D funding, Japan's government R&D funding flowed into its commercial semiconductor industry.[9]

As DOD observed the semiconductor industry shakeout, it naturally became so concerned about the implications for national defense that it chartered a task force of the Defense Science Board (DSB) to evaluate the situation. Although the DSB was particularly concerned about the indirect implications on future sources of supply for custom chips to DOD, the direct effects were felt immediately by "downstream" commercial computer and electronics industries, who lost domestic sources for their day-to-day requirements. Additionally, the "upstream" semiconductor manufacturing equipment firms were affected by the loss of customers as semiconductor firms either went out of business or scaled down their operations. All in all, the semiconductor industry was in poor shape.

The final DSB report provided the following summary to describe the threat to the technological base and our national security:

- US military forces depend heavily on *technological superiority to win.*
- *Electronics* is the technology that can be leveraged most highly.
- *Semiconductors* are the key to leadership in electronics.
- *Competitive, high volume* production is the key to leadership in semiconductors.
- High volume production is supported by the *commercial* market.
- *Leadership* in commercial high volume production is being *lost* by the US semiconductor industry.
- Semiconductor technology leadership, which in this field is closely coupled to manufacturing leadership, will soon reside *abroad.*
- US defense will soon *depend on foreign sources* for state of the art technology in semiconductors. The task force views this as unacceptable.[10]

A prime example of DOD's foreign-source dependency involves the F-18, whose radar is controlled by a chip manufactured by only one firm—Kyocera of Japan.[11]

Not only are semiconductors indispensable to maintaining military strength, they are also critical to our nation's ability to compete in the international marketplace. Since the Japanese semiconductor suppliers are also direct competitors with the "downstream" US industries that supply commercial products, they will have a cost advantage in the components that end up in these items. Further, US firms have complained that the Japanese suppliers have withheld newer generations of semiconductors for their own goods, thereby giving them a head start in developing and marketing new or improved products. As a result of the combined price and technology advantages, the Japanese consumer products readily outsell their US counterparts. If current trends continue, the United States will not only be dependent on foreign sources for semiconductors but also future generations of computers and other technologically advanced products. In simplest terms, whoever controls the semiconductor market will eventually control the computer systems and electronic product markets.

Other concerns flowing from a scenario of dependency on foreign sources for semiconductors include the question of accessibility during a prolonged international crisis; the loss of direct control over the "technology transfer" of advanced chips to our military adversaries; concerns over the potential for deliberate and surreptitious subversion of chips used in critical defense and intelligence systems; and the opportunity for foreign companies/nations to assert leverage over the United States by withholding state-of-the-art chips for business or political reasons.[12]

The DSB report identified several factors contributing to the emerging Japanese dominance. Primarily, these factors concern differences in industrial practices and structure. The Japanese semiconductor firms are subsidiaries of much larger conglomerates that provide the vertical integration and horizontal diversification many feel is necessary to compete effectively in today's world marketplace. Consider that one of today's most advanced semiconductors—the Intel 80386—is reported to have taken four years to develop at a cost of $100 million.[13]

The DSB report also concluded that the Japanese conglomerates have advantages in addition to their greater financial resources for R&D. They provide a captive internal market for some 20 percent of their subsidiaries' semiconductor output, a ready source of low-interest loans, and the financial wherewithal to withstand market downturns better than the smaller US firms—which are generally not subsidiaries of larger firms.[14]

A subsequent interagency study led by the National Science Foundation confirmed these conclusions. It determined that the primary reason for the Japanese

success was not illegal dumping or industrial-targeting but rather that "their huge, diversified companies were better structured to survive in the volatile market for mass-produced memory chips. When chip prices fell, the companies had profits from televisions, personal computers, and microwave ovens to fall back on."[15]

Other factors that the NSF report stated are responsible for Japanese success include: (1) a faster growing home market for chips that were incorporated within their booming consumer export products; (2) their focus on long-term payoffs, which enables them to readily accept short-term losses as a normal cost of doing business; (3) widespread and continuous industry collaboration and communication under the auspices of MITI; (4) an exceptionally skilled technical manpower base; and (5) greater emphasis on manufacturing technology.[16] The NSF report concluded that although the US industry in 1977 led the world in virtually every aspect of semiconductor technology, the Japanese have now either surpassed the United States or are rapidly closing the gap in almost every other category.[17]

As a direct result of the DSB report, Congress approved the government's participation in the Semiconductor Manufacturing Technology (SEMATECH) consortium, which was established to specifically combat the problem of increasing dependency on foreign sources for semiconductors. The Defense Advanced Research Projects Agency (DARPA) will be responsible for funneling the $125-million-per-year government contribution for a period of five years. Besides matching this sum, industry participants will commit another $100 million per year in internal research and development funding. Private sector participation, which is restricted to domestic firms that maintain domestic semiconductor manufacturing capabilities, is comprised of 14 firms that account for 80 percent of the US semiconductor manufacturing capacity.[18] The firms are IBM Corporation, AT&T Company, Digital Equipment Corporation, Texas Instruments Incorporated, Harris Corporation, Hewlett-Packard Company, Intel Corporation, Micron Technology Incorporated, Advanced Micro Devices Incorporated, LSI Logic Corporation, Motorola Incorporated, National Semiconductor Corporation, and Rockwell International Corporation.

The SEMATECH effort closely parallels Japanese industrywide efforts under MITI, whereby cooperative research efforts are coordinated to avoid unproductive and costly duplication of effort. The primary goal of the consortium is to advance existing high-volume manufacturing processes—a segment of the industry in which the US market share has fallen from 100 percent to 10 percent.[19] Along with the focus on developing state-of-the-art commercial manufacturing techniques, DOD hopes SEMATECH's developments will lead to significant semiconductor improvements, which can be used to improve our weapon systems that are increasingly dependent on sophisticated electronics components.

The memorandum of understanding between the government and the consortium specifies that DOD may use the

> intellectual property, trade secrets and technical data developed by SEMATECH and may transfer them to DOD contractors working on government contracts. However, contractors who are not members of SEMATECH may not use the transferred data for any commercial venture. Further, transfer of the data to non-US firms is prohibited.[20]

Many industry experts advised caution before the government gets too involved in such industry-government R&D efforts. In response to the announcement of the formation of SEMATECH, one *Wall Street Journal* editorial-page column contained the following questions:

> Are the companies really committed? The money [each member must contribute] would suggest they are. But there are also rumors of company executives muttering that they might not send their best engineers to work on this project. Equally, there is very real concern that when it comes time for all the participants to hand over their manufacturing knowledge to the project, some may choose not to reveal some proprietary processing tricks.[21]

Despite these concerns, early company actions indicate that SEMATECH has started out on the right track. For example, industry leaders IBM and AT&T have both signaled their intent to provide up to 25 of their best technologists to facilitate the transfer of each company's most advanced memory design and manufacturing processes to the consortium. Responding to questions about its motivation for turning over such valuable proprietary information, William J. Warwick, president of AT&T Microelectronics, stated:

> First and quite selfishly, SEMATECH's success will help us as a company. We believe that SEMATECH will strengthen the semiconductor industry in the United States. And, while the industry includes competitors in semiconductors, it also includes many suppliers to AT&T. We cannot and do not want to make every component that we use in our systems.[22]

Machine Tool Industry

As documented in chapter 1, the domestic machine tool industry is also facing intense foreign competition. At the forefront of the industry's problems has been its failure to continually provide state-of-the-art technology and product quality.[23] Any assembly line downtime can have an expensive ripple effect on the rest of a plant's operations. Therefore, the quality and reliability of computer-controlled production tools such as lathes and milling machines are critical to productivity and profitability. Over the past several years, General Motors (GM) has acquired 100 highly automated presses valued at $2.5 billion. It purchased a total of 88 from Japanese and German firms and 12 from an American firm. Explaining the rationale for

selecting its suppliers, GM's executives stated that their decision was based on the company's need for the latest technology and that a low price was not the overriding factor.[24]

While price may not have been a driver in the GM decision, this is not necessarily true for other purchasing activities. Where price has been a key factor, US firms have noted that they have been consistently underbid by foreign competitors. Believing that the very existence of the industrial base was in jeopardy, the industry looked to Washington for help. Section 232 of the Trade Expansion Act is the primary government vehicle used to determine the debilitative effects of imports on national security, and it provides the mechanism to restrict such imports when harm can be documented. However, according to Sen William Roth (R-Del.), investigations under Section 232 "often get caught up in the Administration in the standard dispute between free trade and protectionism, whereas the focus should be on national security."[25] As a result of the political infighting, a final decision can be indefinitely delayed. For example, during the three-year period that the machine tool sector was under investigation, 25 percent of the domestic industry disappeared. (The primary reason for the delay was the administration's preference for diplomatically resolving the issue by negotiating "voluntary" import restraints rather than pursue punitive Section 232 action.)[26]

Largely because of frustration with the investigation delays, its anger over DOD's inaction to protect the industrial base, and its concern over the country's trade and national security problems, Congress passed legislation restricting DOD's procurement of 22 designated categories of machine tools to US or Canadian suppliers during fiscal year 1988.[27] By this action, Congress sent a clear message that it fully expects DOD to look after the national security interest with respect to any threatening erosion of the industrial/technological base. This action was taken despite DOD's objections that awards to foreign firms are important to international stability and a cooperative spirit, with the added benefit of lower costs through increased competition. Obviously unreceptive to DOD's argument, Congress maintained that its primary concern was "national defense preparedness."[28]

In an attempt to address the causes rather than the symptoms of the machine tool industry's problems, DOD has joined with industry to establish the National Center for Manufacturing Sciences, headquartered in Ann Arbor, Michigan. DOD will provide $5 million per year (1988–90) for research of basic problems associated with high-tech manufacturing, such as microscopic precision techniques, advanced material processes, machine tool design, and the development of a new set of machine tool controllers. The nearly 100-member firms will share the information derived from the research to develop better manufacturing machinery that will help American firms produce competitive products and thereby reverse the downward trend of the industry's market position.[29]

Space Launch Industry

Perhaps no example illustrates the severity of our technological decline and its resultant impact on national security better than the space launch industry. In the early days of the space program, the National Aeronautics and Space Administration (NASA) contracted for the development of expendable launch vehicles (ELVs) that were used to launch government and commercial payloads. The government contracts helped create an industry that was unrivaled in its dominance of the world market. However, with the advent of the space shuttle (which was designed to accommodate all known payloads), NASA regarded the continued viability of the private launch industry as a threat to the shuttle and, according to Milton Copulos, a space analyst at the Heritage Foundation, "tried to do everything they could" to make sure the private ELV industry did not jeopardize support for the shuttle.[30] NASA not only imposed multiple restrictions on firms seeking to test private boost vehicles but also used its leverage to induce shuttle users to design their satellites exclusively for shuttle launches. Further, NASA subsidized launch charges for shuttle payloads, thereby denying rival private launch firms a reasonable chance of winning commercial-sector business.[31] Ignoring a 1984 presidential policy statement advocating the "development of a domestic ELV industry," NASA continued its monopolistic marketing and pricing practices. Consequently, the once healthy and vibrant domestic ELV production industry virtually disappeared.

The error of the policy to rely on the shuttle as the exclusive US boost vehicle became all too apparent with the *Challenger* disaster. The resulting impact of NASA's self-indulgent practices has been devastating. Many of DOD's most [illegible] satellites have been grounded because of the nonavailability of alternative boost vehicles. As our space industry stagnates, the capabilities of our primary adversary continue to grow. For example, while the United States attempted only nine launches in 1986—of which only six were successful—the Soviet Union attempted 91 launches, of which 90 were successful.[32] The efficiencies/economies of scale resulting from a highly active launch sector have allowed the Soviets to openly market their launch services at a fraction of the price that a Western nation could offer.

Six weeks after the *Challenger* accident, NASA finally admitted the folly of its attempt to monopolize the domestic space launch market when acting NASA Administrator William R. Graham stated that "the US is looking forward to the development of a viable, competitive, domestic commercial [launch] capability."[33] President Reagan also weighed in when

he ordered that NASA stop carrying most commercial payloads aboard the space shuttle as an encouragement to commercial industry to reenter the market. Further, a recent presidential directive on space policy requires government agencies (e.g., NASA, DOD, and the Department of Energy [DOE]) to "utilize commercially available goods and services to the fullest extent feasible and avoid actions that may preclude or deter commercial space sector activities."[34]

Clarence J. Brown, deputy secretary of commerce, summarizes this situation succinctly: "The experience with the shuttle program demonstrates how government can frustrate private economic development in the name of helping it."[35] So, while McDonnell Douglas, Martin Marietta, General Dynamics, and others furiously work to get back up to speed, foreign firms have an assured monopoly on Western commercial launches. For example, Arianespace S.A., a European consortium, has customers for all its planned launches through 1990, with anticipated revenues of $2.5 billion.[36] In fact, even the Soviets and Chinese have offered to launch our satellites—at half the price that our weakened industry can offer.[37]

Superconductivity Technology

The recent breakthroughs in superconductivity research have caused unprecedented excitement in the scientific and technological communities. Superconductivity is a process in which electricity can be transported through wires without resistance or power loss. This technology is considered to be in its infancy even though it was first observed in 1911. The major obstacle to widespread use of superconductive materials has been the fact that the phenomenon is observed only at extremely low temperatures. Since 1911 that temperature had been –269°C. Then, in the 1986 breakthrough that generated worldwide attention, a metal oxide ceramic superconducted at –243°C. Remarkably, less than a year later scientists discovered that an yttrium barium copper oxide compound superconducted at –175°C which is still too low for practical applications. The research continues for materials that will superconduct at even higher, and therefore commercially viable, temperatures.

Among the potential military applications for superconducting materials are sensors to detect extremely quiet submarines, energy-storage devices for directed-energy weapons, electromagnetic guns and launchers, magnetic shields, free-electron lasers, and high-power radars that will transmit radio signals across the frequency spectrum. Naturally, there are also numerous dual-use applications for superconductor technology. These include new methods for oil exploration, extremely fast supercomputers, and high-current density conductors for electric motors.[38]

President Reagan has stated that it is imperative for the United States to be the first to develop new products that utilize superconductivity. Many people believe that it is the symbol around which the nation can prove that it can "compete" in the high-technology marketplace. To this end, President Reagan has established a government-sponsored program to harness the combined resources of government, industry, and academia into one big research effort. Major components of the program include:

- Establishment of research centers at the Argonne, Lawrence Berkeley, and Ames national laboratories and at the National Bureau of Standards Laboratory in Boulder, Colorado.
- Allocation of $150 million to DOD for the 1987–1989 period for superconductivity research on military systems.
- Expansion of antitrust laws to allow corporations to enter joint research ventures.
- Amendment of patent laws to provide protection against infringement by foreign firms.
- Tightening of the Freedom of Information Act rules to prevent disclosure of government laboratory information to foreigners.[39]

The Issue

Concerns over international competitiveness and foreign-source dependency promise to be high on the national agenda for the remainder of the 1980s and beyond. As demonstrated in this chapter, government action/inaction can either foster or inhibit domestic industry capabilities. It is clear that the government must serve as a catalyst to ensure that the nation maintains a competitive industrial/technological base. Where national security interests are involved, DOD must take an active role in national policy decisions. The Defense Procurement Act of 1950 specifically tasks DOD with the responsibility to ensure that the "national interest" is maintained with respect to the industrial base. This tasking specifically includes ensuring that the nation is not subjected to undue foreign-source dependency for critical products.

Except for the superconductivity example, most government initiatives to help the domestic base have occurred long after the damage had already been done. Of course, DOD does not operate in a vacuum when trade issues are involved and therefore can share the blame with other government activities and industry. Besides DOD, the other key government players in this area include the White House, Congress, the Office of the US Trade Representative, and the Departments of State, Labor, and Commerce.

However, the balance between healthy competition and protection of key domestic sources is not an easy one. Not all proposed initiatives are deemed to be in the nation's best interest. Recently, many sectors of industry vital to national security have been urgently requesting government help against what they consider to be an onslaught of foreign competition. In response to one such request from the domestic precision-optics industry, DOD rejected a proposed regulation extending protection to the industry despite the fact that the proposal had been based on a June 1987 report by the

Joint Logistics Commanders (JLCs), who concluded that the domestic industrial base for precision optics had declined to a level that jeopardizes national security.[40]

Not only did Deputy Defense Secretary William Taft IV reject the JLC recommendation, but he also rescinded a 1984 memorandum signed by the under secretary of research and engineering that required the purchase of certain precision optics from domestic producers. Secretary Taft stated that the "restriction would have a major effect only on the high-technology defense-oriented optics sector, while having little influence in the low-technology commercial sector where major erosion has occurred."[41] Further, the regulation would have undermined cooperation with European allies, especially those who had been actively solicited for participation in the SDI program.

Similarly, another JLC report found that

> the US bearing industry, having been subjected to foreign penetration of the domestic market for an extended period of time, and having suffered the natural consequences of this lost market share, is in imminent danger of being unable to support national defense needs.[42]

This time, however, Secretary Taft approved a proposed federal acquisition regulation prohibiting DOD from procuring any non-US bearings for three years.[43]

As detailed above, maintenance of the industrial base is a complex issue, and many times individual members within DOD cannot agree on a particular course of action. In general, DOD opposes broad-based protectionist policies, especially when the affected industry is in its sunset years. Under Secretary for Acquisition Robert Costello is adamant in his point that "some would have us subsidize obsolescence, and we don't want to do that." However, he said DOD would be willing to help certain *strategic* industries "when they lay out a plan to become competitive worldwide."[44]

The following chapters of this report analyze in detail the competitive status of a commercial industry that is at the leading edge of technology and that is vital to national security—the supercomputer industry.

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Chapter 3

History of High-Powered Computers

The government first took the initiative to develop a high-powered computer during World War II. At that time, the Army found itself having to perform laborious trajectory calculations for its artillery. Manual computation of just one such trajectory for a given set of firing conditions took specialists several hours using a desk calculator. Seeking a more efficient method, the Army financed the development and construction of a 30-ton, 1,500-square-foot behemoth electronic numerical integrator and computer (ENIAC). Although not completed until after the war, ENIAC was productively employed for weather forecasting, wind-tunnel design, and the study of cosmic rays in addition to its original tasking—the computation of ballistics tables. The capability to perform 5,000 additions or 1,000 multiplications per second enabled ENIAC to complete calculations in 30 seconds that would have required 20 hours on a desk calculator.[1]

Aided by government-sponsored research and development contracts, great strides in computing capability continued throughout the postwar period. With the introduction of the Control Data Corporation (CDC) 6600, which was delivered to Lawrence Livermore National Laboratory in 1963, the term *supercomputer* first came into widespread use. Today, the term continues to be applied to the class of the most powerful computers available in respect to speed, memory capacity, and precision.

One simple measure of computer performance is the rate at which it can carry out floating point operations—which are essential for accurate high-speed mathematical calculations. The acronym for this measure is FLOPS, which stands for floating point operations per second. The CDC 6600 was the first computer to be rated at one megaFLOPS (one million FLOPS), a capability that earned it the title of *supercomputer.* Several subsequent generations of supercomputers have led to present-day state-of-the-art machines such as the ETA-10G, which is rated in the 10 gigaFLOPS (10 billion FLOPS) range. Future generations in the 1990s may be capable of operating in the teraFLOPS (trillions of FLOPS) range. (Incidentally, although many within DOD may be familiar with processing speed measurement in "millions of instructions per second" (MIPS), that measure is useful only for comparing machines of similar architecture and is not recommended as a standard for comparing supercomputers.)[2]

One readily comprehensible example illustrates existing supercomputer power. A calculation that requires 80 hours on an Apple II, 35 hours on an IBM PC, or seven minutes on a VAX 11/780 mainframe can be performed on a Cray X-MP/48 in less than two seconds.[3]

Supercomputers, which have been called the key to the information age, are expensive machines. A complete supercomputer system can cost between $15 million and $25 million. At the end of 1987, there were only about 300 supercomputers installed throughout the world. The majority of the 140 or so machines in the United States are owned by the government—particularly the Department of Energy. For example, Lawrence Livermore National Laboratory owns 14 supercomputers, Los Alamos National Laboratory 10, and Sandia National Laboratories nine. Overall, the industry has been experiencing a phenomenal 25-percent growth rate throughout the 1980s as the commercial sector has become increasingly familiar with this powerful tool. The installed base is predicted to reach 1,000 by 1990 as new users such as the airlines and financial institutions acquire numerous systems.

Supercomputer Applications

The supercomputer is truly a dual-use (civilian and military) product. Examples of its many current scientific applications are documented below.

Computational Fluid Dynamics

Computational fluid dynamics, which is the computer simulation of the motion of fluids, is increasingly important to the aerospace and automotive industries. For example, military and commercial aircraft designers are using this capability to complement (and sometimes replace) wind-tunnel testing. Rather than having to review and evaluate reams of printouts, design engineers can use graphics software packages to visually observe time-sequenced pressure variations on the surface of aircraft in the form of color differentials as the aircraft is put through its paces. The graphics packages also enable the designers to rotate the three-dimensional display to view the aircraft from a variety of angles.[4]

Supercomputers were invaluable in the design of the Boeing 737-300. As a result of increasing market

pressures to produce a more fuel efficient airplane, Boeing decided to modify its existing 737-200 model by lengthening the airframe and changing the engines. The key engineering concern was that the newer, more fuel efficient engines were larger and heavier than the existing ones. Consequently, they could not be mounted under the wing as the older engines had been because the larger engines would not have adequate ground clearance. Boeing engineers believed the engines could be mounted in front of the wing instead of under it in order to obtain the required ground clearance. However, previous attempts to do this on other airframes had failed because wind-tunnel testing revealed unacceptable levels of drag from such a configuration.[5]

With the advent of the commercial use of supercomputers, the engineers were able to use a Cray instead of a wind tunnel to evaluate the 737-300 design. Unlike previous wind tunnel tests, when the supercomputer also showed excessive drag, the engineers were able to precisely determine what was causing the interference. They then manipulated the aircraft's design on the supercomputer in order to find the optimal configuration that would reduce the drag. The final solution involved altering the design of the upper part of the engine's nacelle into an asymmetrical shape that all but eliminated the drag.[6]

From a DOD perspective, supercomputers have also provided cost- and time-saving benefits with respect to military aircraft design. For example, full-scale fabrication and repetitive bird strike testing of a new F-111 canopy took four years and cost $5 million. However, supercomputer simulations of 18 various canopies for the proposed T-46 aircraft required only one round of testing at a cost of $20,000 for leased supercomputer time.[7]

Computer-Aided Vehicle Design and Analysis

Supercomputers are widely used in the automotive industry. Vehicle designers can computationally test the strength and vibrational response of key structural components, simulate the effects of a crash, replicate the flow and dynamics of combustion chambers, and design a vehicle that is aerodynamically smooth and fuel efficient. In the past, designs could only be evaluated by building and testing full-scale models—a costly and time consuming process. However, supercomputers enable engineers to rapidly evaluate numerous alternatives without ever having to build such models.[8]

For example, Ford Motor Company designed its 1986 Taurus car on a supercomputer, evaluating six times as many designs as the industry average. Not only could it compare numerous alternatives, but Ford also saved $6 million in design and testing costs by not having to build numerous Taurus prototypes.[9] Other automobile manufacturers owning supercomputers include General Motors, BMW, Volkswagen, Mercedes-Benz, Toyota, Nissan, Honda, and Chrysler.

Similarly, the Army Tank Automotive Command (TACOM) is using a Cray-2 to ensure selection of the optimum design of its future tanks. In addition to the design cost and acquisition time savings, TACOM intends to improve the vehicles' mission capabilities through such improvements as a smoother ride, weapon stability, and maximum signal suppression. These technical improvements will be the result of supercomputer-aided predictions of shock and vibration levels as well as structural integrity analysis.[10]

Biochemistry

Based on the mathematical theory of quantum mechanics, it is possible to use supercomputers

> to calculate the structure and interaction of molecules relevant to biochemical systems. Molecular dynamics uses this information to describe the motion, deformation, and rearrangement of large molecular systems. The combination of enormous computational power and sophisticated interactive graphics systems allows scientists to explore in unprecedented detail biochemical processes such as the behavior of DNA in a solvent, or the mechanism of drug/enzyme interactions.[11]

DuPont is currently using a supercomputer to model the shapes and interactions of molecules to help it isolate those that are likely to prove safe and effective. This process conserves time and money by narrowing the range of molecules that must be produced and tested in a laboratory. Similarly, the National Cancer Institute is using a supercomputer to study "genetic sequences and structures in hopes of discovering the underlying molecular mechanisms that cause cancer."[12]

Weather Forecasting

Accurate weather forecasting is critical to both military and civilian sectors. For example, military and commercial pilots both need accurate weather data to plot flight paths. Farmers are also dependent on weather forecasts for long-term decisions, such as when to plant, spray, fertilize, and harvest crops. Prior to making its national and worldwide predictions available, the National Meteorological Center uses a supercomputer to make sense of the inordinate amount of data generated by a vast network of 9,000 manned ground stations, 750 weather balloons, thousands of marine buoys, a fleet of 2,000 ships, and some 600 aircraft. In addition to having to consider such inputs as temperature, humidity, barometric pressure, and wind conditions, the forecasting task is further complicated by the fact that atmospheric models must accurately account for numerous physical phenomena to include evaporation and condensation, solar heating, and cloud movement.[13]

Petroleum Exploration and Production

Petroleum companies use specially designed hydraulic devices to induce shock into the ground, and then use a supercomputer to analyze the sound waves that are reflected back to the surface. In addition to the sheer volume of raw data generated by the shocks, the geological mapping process is confounded by extraneous data caused by distortions, reverberations, and noise associated with the shock. Supercomputers with their vector-processing capability can perform the required three-dimensional analysis in a timely and cost-effective manner. By reviewing the computer output, geologists can better predict the presence or absence of petroleum.[14]

Not only can they help locate oil reservoirs, supercomputers can also be invaluable tools during the extraction process. Since subsurface natural pressures will not be sufficient to push all of the oil to the surface, recovery operations require the delicate procedure of injecting just the right amount of water (mixed with a surfactant) into the reservoir to mobilize the trapped oil and push it to the surface. Supercomputer simulation takes into account such diverse factors as the underground temperature, pressure, the chemical makeup of the petroleum, and the field's geology when determining the optimal strategy for recovering the oil. Exxon has credited its supercomputer with a 13-to-18 factor increase in process efficiency while Arco credits its system with a 7-percent increase in its Prudhoe Bay, Alaska, recovery operation—a savings of $21 billion.[15]

Nuclear Weapons and Delivery Systems Design

The world's principle user of supercomputers is the Department of Energy, which owns approximately 15 percent of the installed base.[16] In the 1960s DOE used the first supercomputer—a CDC 6600—to perform the complex computations required in the design of nuclear weapons and the analysis of up to 50 nuclear tests per year. Because the events that take place during a nuclear explosion are very complex and occur in fractions of a second, they are extremely difficult to measure. However, supercomputers can simulate what takes place during this process, thereby contributing to improvements in the safety, reliability, and yield of nuclear weapons.[17] Even when the Nuclear Test Ban Treaty severely constrained nuclear weapons detonations, DOE's research laboratories were able to limit their detonations to 20 per year without significant adverse effect by using the more powerful supercomputers of the 1970s and 1980s for improved simulations.[18]

Similarly, the design and testing of reentry vehicles (RVs) has been aided through the use of supercomputers. Ralph Maydew of Sandia National Laboratories has estimated that the costs of instrumented flight-tests for six different RVs would be $12 million. The same tests conducted in a wind tunnel would cost $3 million. A supercomputer simulation would only cost $300,000.[19]

Sandia has also used supercomputers to simulate aircraft-delivered payloads. The inherent dangers of weapon separation during flight-testing of newly developed weapon systems are minimized by simulating weapon separation on a supercomputer before the weapon is ever placed on an aircraft. Such simulation not only minimizes the danger to the aircraft and crew but also saves costs and time that would otherwise be spent on wind-tunnel and actual drop tests.[20]

Space Flight

All three of NASA's research centers (Ames, Langley, and Lewis) have supercomputers for such esoteric applications as computational aerodynamic research, internal computational fluid mechanics, thermal and structural performance analysis of propulsion system components, and atmospheric science investigation. Additionally, even though it is not designated as a research center, the Goddard Space Flight Center also has a supercomputer.

Victor L. Peterson, director of aerophysics at Ames, believes the supercomputer is "as important a breakthrough as that of the wind tunnel and the first powered flight."[21] Ron Bailey, chief of the Numerical Aerodynamics Simulation program at Ames, adds that "supercomputers are as significant to pioneering research today as calculus was to Newton."[22] The aerodynamics engineers at Ames will use their Cray-2 to help design the National Aerospace Plane, which will operate at speeds approaching 17,000 mph. The supercomputer will simulate the tremendous aircraft stresses and heat transfer inherent in ultrahigh-speed flight, thereby allowing engineers to study the airframe and its performance in respect to structural integrity, engines, and overall handling.[23] Before the advent of supercomputers, such stress testing was accomplished in wind tunnels. However, there are no wind tunnels that can model the impact of anything close to Mach 25—the expected speed of the National Aerospace Plane. In fact, the maximum capability of a modern wind tunnel is only Mach 8.[24]

Supercomputers have also been used to solve real-time problems. For example, postflight inspections of the space shuttle revealed that the main engine had been damaged as an apparent result of fuel-flow problems. Due to the extreme heat generated in that area, it was not feasible to attempt to replicate the problem during ground testing. When NASA engineers turned to their supercomputer for help, engine performance simulations revealed that the flow of fuel from the center fuel duct in the main engine powerhead disrupted flow in the outer fuel ducts. Following corrective action, the fuel flow increased significantly, resulting in increased engine power and reliability.[25]

Communications Security/Intercept

Colossus, an early electronic computer, helped decipher German codes during World War II. Since the first models were developed, government security agencies—such as the National Security Agency (NSA)—have been among the leading customers of the supercomputer industry. Today supercomputers with their extraordinary capability for manipulating the sophisticated algorithms used for data encryption are tasked with protecting our nation's sensitive communications while simultaneously deciphering the encoded messages of our adversaries (actual and potential).[26] In its pursuit of even more powerful supercomputers to gather and analyze intelligence data, the NSA has established its own research center in an attempt to develop a supercomputer a thousand times more powerful than today's models.

Electronics Design

Designers of today's complex electronic circuits are using the computer-aided design features of supercomputers to develop new products. This is particularly true in the semiconductor industry, where chips have become increasingly more difficult to design as they shrink in size. Since the product life cycle of a new class of chips is exceedingly short, the first company to market its product has a significant advantage over the competition. For example, a supercomputer helped AT&T to be the first to market the one-megabit chip, which is well known for its high quality. Its error-free design is attributable to AT&T's ability to perform numerous design simulations of the physics and chemical interactions taking place on a chip before selecting the optimal design.[27]

Not surprisingly, both CDC/ETA and Cray are using their own models to design the next generation of supercomputer hardware and software. Similarly, Apple uses a supercomputer to design and simulate its new products.[28]

Purely Military Uses

The ability to use a supercomputer to track the thousands of warheads launched by the enemy, discriminate between actual warheads and decoys, calculate interception vectors, and control the defensive weapon systems—all in the short time interval between launch and impact—is one of the primary prerequisites for an effective SDI system. In SDI's developmental stage, two Cray supercomputers form the heart of SDI's National Test Bed located at Falcon Air Force Station, Colorado Springs, Colorado.

Supercomputers can also be used to detect enemy submarines by sorting and filtering out various ocean noises. In fact, the Navy can acoustically track a submarine according to its unique noise "signature." Along these same lines, space- and ground-based sensors can sort and filter out various surface noises to identify cruise missiles.[29]

International Competition

A 1987 Society for Industrial and Applied Mathematics (SIAM) workshop report concisely summarizes the importance of supercomputers to the nation's wellbeing:

> High-performance computing has emerged as a powerful and indispensable aid to scientific and engineering research, product and process development, and all aspects of manufacturing. This tool is critically important to the competitiveness of broad segments of America's technological industries and scientific enterprise. . . . It is now widely recognized that high-performance computing leads to economically significant benefits in such diverse industries as aerospace and pharmaceuticals, and that it is a cornerstone of the nation's defense system.[30]

Identification of Firms Involved

To better comprehend the issue of international competition in the supercomputer market, an introduction to the six key firms in this market is necessary.

Control Data Corporation (CDC)/ETA Systems, Inc., Minneapolis, Minnesota. Control Data is the world's eleventh largest data-processing company with $3.3 billion of revenues in 1986.[31] As previously mentioned, the CDC 6600 was the first high-powered computer to be widely referred to as a supercomputer. With the introduction of the 6600 in 1963 and the follow-on 7600 in the early 1970s, CDC enjoyed a monopoly on the worldwide supercomputer market. Then in 1976 the newly formed Cray Research introduced the Cray-1, a direct and more powerful competitor of the 7600. It was not until 1980 that CDC could introduce the Cyber 205, a supercomputer roughly equivalent to the Cray-1.

In 1983, in an attempt to recapture its position of preeminence in the supercomputer market, CDC established ETA Systems as a subsidiary that concentrated all its efforts on supercomputer technology. CDC was gambling that an autonomous subsidiary would be able to attain innovative and speedy results if it were removed from the stifling constraints of the day-to-day oversight by the CDC bureaucracy. The gamble began to pay dividends in 1987 when the ETA-10 product line was introduced. The ETA-10G was the top-end model with an expected peak rating of 10,000 FLOPS (equivalent to 10 gigaFLOPS)—a supercomputer that could lay claim to being the world's fastest.

A key marketing advantage for ETA is that the installed base of CDC Cyber 205s is upwardly compatible with the ETA-10 line. Further, ETA has a state-of-the-art manufacturing facility where it can mass-produce supercomputers with a minimal amount of labor. However, on the negative side, while Cray has more than 500 application packages for its supercomputers, ETA has only 105.[32] At the beginning of

1988, ETA-10s and the out-of-production CDC Cyber 205s accounted for 13 percent of the world market.[33]

Cray Research, Inc., Minneapolis, Minnesota. Cray Research is the world's 56th largest data-processing company with revenues in 1986 of $600 million.[34] Before Seymour Cray founded Cray Research in 1972, he worked at CDC, where he designed both the 6600 and 7600. Since the introduction of the Cray-1, Cray Research has dominated the world market. By constantly developing more powerful models—such as the Cray X-MP, Cray-2, and Cray X-MP/4—Cray has been able to capture almost two-thirds of the world supercomputer market, and it controlled 21 percent of the Japanese market at the beginning of 1988.[35] The Cray X-MP introduced in early 1988 is rated at three gigaFLOPS, while the Cray-3, which is expected to be introduced late in 1989, may approach 10 gigaFLOPS.

One of Cray's strengths is its extensive library of 500-plus software applications. No competitor has more than 105.[36] Another strength is that it is building a state-of-the-art manufacturing plant for the production of Cray-3 components.

IBM, Armonk, New York. IBM is the world's largest data-processing company with revenues in 1986 of $50 billion.[37] Inclusion of IBM in the group of the world's preeminent supercomputer firms is somewhat debatable. Some industry experts contend that rather than rank it at the bottom of the supercomputer line, IBM's most powerful model—the 3090 (with vector-processing installed)—is more appropriately situated at the top of the mainframe line.

Although its inclusion with the elite may be suspect today, IBM's prospects for the 1990s appear promising. Until late 1987 Cray's product development was driven by two independent teams. One was led by Seymour Cray and the other by Steve Chen. The teams took turns leapfrogging the designs of the other, thus enabling a constant and rapid introduction of improved products. Chen was responsible for pioneering the use of multiple processors within supercomputers. However, as a result of a falling out over the continued development of a technologically ambitious and expensive multiprocessor project, Chen departed Cray and formed his own company, Supercomputer Systems of Eau Claire, Wisconsin. In late 1987 IBM announced it would provide financial and technical support to Chen's effort to develop a supercomputer with 64 large processors working in parallel. This new supercomputer would be 100 times more powerful than any that existed in 1987.[38] The financially driven tie-in with IBM is significant for cash-poor Supercomputer Systems because IBM's market value of $99 billion exceeds that of the other five supercomputer firms combined.[39]

Nippon Electric Company (NEC), Japan. If one considers only its data-processing business, NEC is the world's fifth largest data-processing corporation, with 1986 revenues of $6.3 billion.[40] Further, NEC is the world's 40th largest publicly owned corporation with a market value of $20.7 billion, and total 1986 revenues of $14.6 billion.[41] NEC markets its supercomputers through HSNX (Honeywell-NEC Supercomputers, Inc.), a joint venture with Honeywell. In mid-1988 HSNX had only one supercomputer installed in the United States—at the Houston Area Research Consortium (HARC). At the beginning of 1988, NEC controlled 21 percent of the Japanese supercomputer market,[42] while it controlled 4 percent of the world market.[43]

Fujitsu, Japan. If one considers only its data-processing business, Fujitsu is the world's fourth largest data-processing corporation, with 1986 revenues of $6.6 billion.[44] Further, Fujitsu is the world's 91st largest publicly owned company, with a market value of $12.3 billion and total 1986 revenues of $10.6 billion.[45] Fujitsu supercomputers are marketed in the United States by Amdahl and in Europe by Siemens AG. Fujitsu supercomputers are priced millions below the comparable Crays because their design was based on Fujitsu's mainframe architecture. However, they only have about 50 application packages that have been optimized to run on the supercomputer line.[46] In mid-1988 Fujitsu had only one supercomputer installed in the United States—at a Norwegian oil exploration company's Houston office. At the beginning of 1988, Fujitsu controlled 35 percent of the Japanese supercomputer market[47] and 16 percent of the world market.[48]

Hitachi, Japan. If one considers only its data-processing business, Hitachi is the world's sixth largest data-processing corporation, with 1986 revenues of $4.7 billion.[49] Further, Hitachi is the world's 32d largest publicly owned corporation, with a market value of $23 billion and total 1986 revenues of $31.4 billion.[50] Hitachi is concentrating its efforts in Europe and Japan and has not attempted to market its supercomputers in the United States. At the beginning of 1988, Hitachi controlled 22 percent of the Japanese supercomputer market[51] and 16 percent of the world market.[52]

Continued Leadership in Jeopardy?

Although the United States has already lost leadership of several key sectors in the electronics industry, the economic impact of those losses pales in comparison to those at stake in the supercomputer market. While it is readily apparent that a strong domestic supercomputer industry is essential for maintaining US leadership in critical defense and civilian sectors, the Office of Science and Technology Policy (OSTP) recently concluded that our dominance in the supercomputer industry is being challenged by government-supported research and development in foreign nations—primarily Japan. William R. Graham, science adviser to the president and director of OSTP, states that

one thing is clear, the competition in an increasingly competitive global market cannot be ignored. The portion of our balance of trade supported by our high-performance computing capability is becoming more important to the nation. In short, the United States must continue to have a strong, competitive supercomputing capability if it is to remain at the forefront of advanced technology.[53]

Events in the international supercomputer marketplace since late 1986 have brought the problems of this small but vitally important industry into international view.

Japanese Declaration. Within the past decade, Japan has made significant inroads into the world's high-technology market. As part of its plan to be a dominant force in the computer market, the Japanese government sponsored the National Super Speed Computer Project in 1983. The expressed goal of this 10-year program is to develop a supercomputer 1,000 times more powerful than any in existence at that time.[54] This is truly an ambitious undertaking considering that the Japanese supercomputer manufacturers were not represented in the industry until 1983. However, they were able to capture almost one-fourth of the world market by the end of 1987.[55] Such rapid progress is consistent with Japan's goal "to become the world leader in supercomputer technology, marketing, and applications."[56]

Closed Japanese Market? In the past several years, supercomputers have been a major source of trade tension between the United States and Japan. While Cray and ETA have been free to compete for business in Japan's private sector, only two American supercomputers have been sold in Japan's public sector—and then only as suspected "token" purchases in response to US political "pressure." Just prior to that purchase, US Trade Representative Clayton Yeutter and Japanese Ambassador Nobuo Matsunaga exchanged letters outlining new procedures to simplify the bidding process in Japan's public sector, which US manufacturers believed had been "heavily biased against foreign firms."[57]

One related trade issue that still remains a major irritant in relations between the two countries concerns the Japanese practice of heavily discounting supercomputers in order to create markets. According to Assistant US Trade Representative Doug Newkirk, the Japanese firms have sold models in both Japan and the United States at discounts approaching 80 percent.[58] This practice is especially disconcerting to the competitive balance, as reflected in statements made by Gary Holmes, a spokesman for the Office of the US Trade Representative, who observed that Cray and ETA "are small companies and can't afford to compete with [the Japanese] megacompanies that [can afford to] lose millions of dollars to gain a foothold in the market."[59]

Penetration of the US Government Market. In September 1986 the United States Air Force awarded a contract valued at more than $33 million for a complete computer system to support Military Airlift Command's (MAC) peacetime and wartime airlift planning and execution. The system was purchased to enable MAC to optimize flight scheduling, cargo-handling operations, weight balancing, and flight planning. The winning contractor, Honeywell Information Systems (HIS) of McLean, Virginia, underbid the only other bidder, CDC, by more than $10 million. Immediately upon losing the contract, CDC, which had bid a Cyber 205 supercomputer, accused Honeywell of helping NEC Corporation of Japan to dump Japanese high-performance computers into the United States. The allegation was based on the fact that four NEC mainframes constitute the "heart" of the Honeywell system.

Control Data's consternation was exemplified by its Government Systems President Boyd Jones's statement that the Air Force's award for large-scale Japanese computers "really blows my mind, coming at a time when the Defense Department itself is studying how to reduce its dependency on Japanese technology."[60] In a letter to high-ranking US government officials, Jones outlined the following concerns:

- In time of national emergency, replacement parts for the system (which are made in Japan) will have to be shipped from that country in order to maintain the equipment. If supply lines are disrupted, the parts might not be available.
- In order to provide analyst support [when local technicians cannot fix a system problem], it might be necessary to bring in Japanese technicians who might have to access the system while top secret data is still loaded on the system in order to adequately maintain the equipment.
- The HIS bid was $10 million below the CDC bid. This appears to be a situation where NEC will supply its computer at a price far below its material costs alone. This "dumping" of a computer onto the United States military market appears to be a harbinger of the Japanese strategy to dump computers to penetrate the entire US market. This is a major problem for the US far beyond just this one procurement.
- The nation's balance of trade deficit, particularly in the computer industry, is severe. The Air Force's purchase of a Japanese system further contributes to the balance of trade deficit.
- While the US government restricts sales of American corporations equipment [supercomputers] to foreign nations, the Japanese are free to sell their winning system to any nation it desires. So while CDC's market is restricted in the national interests of the United States government, the United States government turns around and purchases computer systems which CDC is forbidden to compete against outside the United States without obtaining an export license.[61]

US Restrictions on Domestic Firms. As mentioned above, the US government restricts the sale of certain high-technology equipment to foreign nations. ETA and Cray supercomputers are among those items on the restricted list. The case described below illustrates the impact of these restrictions.

The government of India had been trying to buy a supercomputer from a US firm since the early 1980s, but such a commercial sale was blocked by the government (primarily DOD) over concerns that India would either allow the Soviets to access the equipment or that it would use the supercomputer to design a nuclear weapon. Coming on the heels of the announcement of the first US deficit in high-tech trade, the proposed sale

split the US government. Paul Freedenberg, the Commerce Department's assistant secretary for trade administration, expressed the concerns of free market advocates: "You don't want to so disadvantage US exporters that you affect their ability to compete in worldwide trade, where the real market is, and undermine your technological base."[62]

At the same time, on the basis of a US intelligence report, DOD concluded that the Indian government was not capable of protecting sensitive US technology. Since the Indians were coproducing Russian MiG-21 and MiG-27 fighters in India, the Pentagon was concerned about the ability of the Soviets to access sensitive supercomputer technology once it was installed.[63]

Representative Don Bonker (D-Wash.), chairman of the House Foreign Affairs Subcommittee on International Economic Policy and Trade, expressed typical congressional concern:

> A coherent US policy doesn't exist when it comes to export controls. There are two forces within the administration with different views. . . . If US firms want to do business abroad, they have to deal with delays, sometimes with denials and at all times with uncertainty.[64]

Pentagon officials were successful in blocking the proposed sale to India until Prime Minister Rajiv Gandhi elevated the issue to the White House in 1985. The Indian government claimed it desperately needed the American technology to help it analyze vast amounts of satellite weather data in an attempt to better predict the arrival of the dangerous annual monsoons. Subsequently, then Vice President George Bush announced the sale would be approved if satisfactory technology protection safeguards could be worked out.[65]

However, even with White House intercession, the proposed sale dragged on for almost two years as the two governments tried to reach agreement on the terms of the safeguards. In the interim, the Japanese government notified India that it would sign an agreement to authorize the sale of a Japanese supercomputer if the US deal fell through.[66] The United States and India were finally able to reach agreement on the sale in late 1987. However, the final terms of the sale successfully denied the Indians their supercomputer of choice—a dual-processor Cray X-MP/24. As a result of Pentagon pressure, the two countries agreed on the sale of a less powerful single-processor Cray X-MP/14, which cost several million dollars less.[67]

This case highlights the difficulty and high stakes involved when trying to reconcile the conflicting goals of international free trade and the safeguarding of dual-use technologies. Further, it demonstrates how a purely commercial firm with *no* government funding can still be subject to government controls that can significantly affect its ability to compete in the world marketplace.

US "Pressure" on Academic Institutions. As of mid-1988 only one Japanese supercomputer, a NEC SX2 purchased by the Houston Area Research Consortium, had been installed within the United States. Since the Japanese supercomputers are new to the market (the first being commercially introduced in 1983), there is a scarcity of applications software in existence when compared to Cray. Therefore, the Japanese firms, particularly NEC, have allegedly targeted US universities for discounted sales in an attempt to (1) establish a "prestigious" market base, (2) to help accelerate software development for their machines, and (3) to familiarize some of the nation's best computer scientists and engineers with their hardware.

Such an example of targeting a prestigious market base occurred in late 1987 when MIT was considering the award of a contract for a Japanese supercomputer but was effectively pressured by the US government to cancel the acquisition. Of five high-performance computer firms seeking the contract (Cray, ETA, HSNX, Amdahl/Fujitsu, and IBM), the proposed price by HSNX was significantly lower than any of the other competitors. The fact that one of this country's most prestigious engineering schools was about to purchase its first supercomputer from a Japanese firm prompted acting Secretary of Commerce Bruce Smart to send MIT provost John M. Deutch a letter warning him that antidumping proceedings might be initiated "if it is determined that the product is being sold at less than fair value and that it is injuring a US industry."[68] Deutch added that other US government officials had stated that "it would not be in the nation's best interest to obtain the machines from Japan."[69] Since MIT is the recipient of a significant amount of federal R&D funding, such high-level government "pressure" was effective in causing MIT to cancel the acquisition. An unidentified director of a university supercomputer center commented that given the trade tensions between the United States and Japan and the amount of research money the federal government controls, his university would not be the first to buy a supercomputer made in Japan—nor would any other university.[70]

Not so coincidentally, the MIT scenario occurred only a few months after the Air Force purchase. As a result of apparent confusion within the government over what the nation's supercomputer acquisition policy should be, one of the country's preeminent academic institutions is without a supercomputer it needs to help educate the nation's future scientific leaders.

Although the situation was certainly not exactly the same, other nations seemed to put the health of their students and researchers ahead of nationalistic concerns. Only weeks after the US government pressured MIT to turn down HSNX's "generous" proposal, IBM announced that it would donate $40 million worth of its supercomputers (the 3090 600E with vector processing) to European universities and institutes in France, West Germany, Belgium, Switzerland, and Italy. The European nations accepted the offer with open arms, despite the fact that European firms market high-per-

formance computers and are engaged in their own supercomputer development projects.[71]

Congressional Restrictions. In reaction to the government's lack of a clear policy on the purchase of foreign-made supercomputers, as evidenced by the differing viewpoint on the Air Force's and MIT's solicitations, Congress levied its own mandate in the fiscal year 1988 continuing resolution bill by restricting DOD procurement of supercomputers to domestic models during the fiscal year. Exceptions to this legislation could be obtained if the secretary of defense "certifies to Congress that such an acquisition must be made in order to acquire a capability for national security purposes that is not available from US manufacturers."[72] Additionally, the legislation required DOD to develop a master plan for the procurement and management of DOD supercomputers.[73]

According to a spokesperson for Representative Martin O. Sabo (D-Minn.), a coauthor of the legislation, the restriction was enacted to

> force the Defense Department to think through and come up with a consistent policy that would preserve the vitality of the US supercomputer industry. We don't want to find ourselves in the same position as the US semiconductor industry several years down the road.[74]

These examples have demonstrated how complex and multifaceted the entire supercomputer issue is. Surely many other "endangered" dual-use technologies face the same situation. The following chapter continues the analysis of the supercomputer competitiveness and possible dependency issue. It also provides the basis for the actions recommended in chapter 5.

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Chapter 4

Supercomputers of the Future: Concerns and Alternatives

Given the vital contribution of supercomputers to the maintenance of our national security in both economic and military terms and their symbolic value as a reflection of our nation's technological prowess, the continued competitiveness of the domestic supercomputer industry is a high-visibility issue. One might therefore expect that calls for government action to "protect" this sector would fall on receptive ears. Justification for intervention could be based on purely technical grounds since there is little doubt that the United States cannot be dependent on foreign sources for so critical a technology. However, as is often the case, this situation is not as staightforward as it may appear.

Concerns over Foreign-Source Dependency

Many of the arguments set forth by CDC government systems president Boyd T. Jones, in reaction to the Air Force acquisition documented in chapter 3, parallel those most often cited when protection from foreign competition is requested. This chapter analyzes CDC's concerns as well as several other issues that should have an impact on the ultimate decision as to whether government intervention is warranted.

Evaluation of CDC's Concerns

As noted in chapter 3, CDC expressed a number of concerns about the Air Force's purchase of a computer system containing mostly Japanese equipment. An assessment of the validity of each concern follows.

Spares May Be Unavailable in a National Emergency. In a national emergency, replacement parts for the system made in Japan will have to be shipped from that country in order to maintain the equipment. If supply lines are disrupted, the parts might not be available.

ETA has for the most part used only domestic-source components in its supercomputers, but the same cannot be said of Cray supercomputers, which contain a significant percentage of critical foreign-source components. To its credit, Cray is working to lessen its dependency, as evidenced by its development of a domestic source for the gallium arsenide chips it will incorporate within its Cray-3 systems. However, in the interim, the argument that the United States is susceptible to a spare parts cutoff cannot be limited to Japanese supercomputers. Any directive to exclude foreign-source end products because of potential spare parts supply problems would not be practical if it favored a domestic supercomputer that contains critical foreign-source components.

Although assured access to spare parts is a key concern, especially if the affected system has a critical national security mission, a contractual requirement to maintain adequate spares within the United States should provide sufficient insurance if a foreign-source end product is purchased. Such a clause should also be included for the purchase of critical domestic-source end products that contain critical foreign-source components. Although the concern about the ability to acquire foreign-source spares in a national emergency is justified, proper utilization of available contractual safeguards could minimize or negate the risk.

To address the remote chance that spare parts would be unavailable in the United States even with such a contractual provision the compact nature of today's supercomputer components would allow virtually any type of long-range aircraft (civilian or military) to ferry required spares to the United States. Of course, such an alternative is feasible only as long as the source nation is willing to supply the spares (and system upgrades). Former Secretary of Defense Caspar Weinberger acknowledged the risk when he asked:

> Can the United States afford to rely on other nations, no matter how friendly, for the technological innovations that are fundamental to our defense? Clearly, the answer is no. Certainly, cooperation and the strength of our alliances can mitigate this concern in peacetime. But predicting international conditions is an imperfect art at best. . . .[1]

While countries such as Japan are undoubtedly our allies today, alliances have a strange way of changing over time for either political or economic reasons. Indeed, the ongoing trade tensions between the United States and Japan have strained relations between the two nations more than most realize. Consider that a 1987 poll revealed that American citizens regard the Japanese as a greater threat to national security than the Soviets.[2] This attitude is certainly a belief that the economic threat overshadows the military threat. Not

surprisingly, Japanese nationalistic sentiments are rising as a result of perceived "Japan-bashing" by the US Congress. Even if the defense alliance does not deteriorate, the source nation could always withhold system enhancements in order to ensure an edge in the world's economic competition.

Required Maintenance Services May Be Beyond Local Capabilities. In order to provide analyst support when the system problem is beyond the capabilities of local technicians to correct, it would be necessary to bring in Japanese technicians who might have to access the supercomputer while classified data is still loaded on the system.

In the majority of cases, the system can be "sanitized" prior to allowing contractor personnel access to the system. However, system sanitization often prohibits a replication of the malfunction. Therefore, it may be necessary to keep the classified data on the system to ensure that a fix can be made. In those instances where classified data remains loaded, the contractor's technicians must have the appropriate security clearance. This poses a dilemma when a system-level deficiency in a foreign-source end product is so complex that the fix is beyond the capability of the contractor's appropriately cleared US citizen field technicians and the contractor needs to bring in a non-citizen system designer to solve the problem. Such a tasking would be impossible since non-US citizen contractor personnel can never have access to a system that still has classified data loaded on it.[3]

Although the scenario requiring the presence of a system designer is certainly feasible, there are several preventive measures that can be taken to minimize the risk. First, since this problem would be primarily limited to the first few production models of a new system (before most "bugs" can be worked out), users should not consider acquiring unproven foreign-source systems for installation within a classified environment. While the same precaution would also hold true for an unproven domestic-source system, the timely availability of appropriately cleared US citizen technicians/system designers minimizes the risk significantly. Based on the Air Force's stated need for "leading-edge"—not necessarily "cutting-edge"—supercomputer technology, it is unlikely that we would ever acquire a firm's first production models.[4] However, our intelligence agencies and national laboratories often do require "the newest and fastest." So this precautionary measure may not be feasible for them.

Second, in order to minimize the risk should the activity require an early production model or if a major system flaw is discovered on a mature foreign-source system, the contract should specify that appropriately cleared US-based technicians must receive the comprehensive technical training required to solve system problems at all levels of complexity. Of course, this is easier said than done. All state-of-the-art firms usually closely guard their proprietary data and are extremely reluctant to divulge this information to outsiders. However, since prolonged downtime is totally unacceptable for most defense activities using supercomputers, a fully trained, cleared, and US-based maintenance force is an absolute necessity. But even if the foreign contractor fully complies with this requirement, the task of training technicians on all levels of maintenance procedures is formidable and certainly carries a risk to the government regarding its achievability.

Foreign Firms Marketing Practices Put US Firms at a Disadvantage. The HIS bid was $10 million below the CDC offer. This appears to be a situation where NEC will supply its hardware at a price far below its material costs alone. This "dumping" of a computer onto the United States military market appears to be a harbinger of the Japanese strategy to dump computers in an attempt to penetrate the entire US market. This is a major problem for the United States far beyond just this one procurement.

A review of the contract in question indicates that although the overall price differential between the two offers was in the $10-million range, a comparison of the line items does not indicate an abnormally wide disparity between the hardware portion of the bids. Actual differences can be partially explained by the fact that HIS had a price advantage because it was able to meet contract requirements by bidding several NEC mainframes, while CDC bid a Cyber 205. Thus, by not having to bid an expensive supercomputer, the HIS/NEC team was able to keep its hardware prices and support costs below CDC's.

Although dumping allegations could not be substantiated in this procurement, the seriousness of such a practice is self-evident. The Japanese have a long track record of discounting products dramatically in order to capture market share—even if such practice results in a loss over the short run. In the supercomputer sector, the three Japanese conglomerates have substantial financial resources, while the US firms by comparison are very small and cannot afford to compete in a deep-discounting environment.

The US supercomputer firms had expressed their concerns about Japanese marketing practices before the events associated with the Air Force contract. However, the visibility given the Air Force acquisition at the upper levels of government surely provided an impetus toward high-level trade discussions between the nations to resolve two primary supercomputer issues. One involved American perceptions of a "closed market" for US supercomputers in Japan's public sector. The other naturally concerned allegations that the Japanese were offering systems at tremendous discounts, both in Japan and in the United States.

From the US perspective, even though our firms clearly dominated the world supercomputer market in the early 1980s, only 13 of the 46 supercomputers installed in Japan between 1980 and 1987 were American systems. Even more interesting, until the

Japanese public sector bought two US supercomputers in 1987 in response to political pressure, all the previous 11 US systems had been purchased by Japan's private sector. So while US firms controlled 50 percent of the Japanese private-sector market, they could only capture 8 percent of the public-sector market (zero percent prior to the "pressure"). Based on the above breakout, there were allegations that the Japanese government had delayed its purchase of supercomputers during the early 1980s awaiting the arrival of the three Japanese firms. Not surprisingly, upon their entry into the market, the three "infant-industry" firms sold 22 systems to Japan's public sector before the first US system was purchased. From another viewpoint, even though the US firms controlled 75 percent of the world's supercomputer market at the end of 1987, the Japanese firms controlled 72 percent of the Japanese market.[5]

Addressing this perception of an apparently "closed" public-sector market in Japan, US Trade Representative Clayton Yeutter and Ambassador Nobuo Matsunaga of Japan conducted months of negotiations in 1987 attempting to find an amicable solution to the problem. The discussions culminated in an agreement whereby new administrative procedures in Japan's public-sector acquisition policies were established in an attempt to eliminate the hidden barriers to US supercomputer firms.

Even though Cray and CDC/ETA were obviously pleased with the agreement, the firms maintained that the unresolved dumping issue was a more critical obstacle to fair competition than the secretive bidding practices for Japanese government contracts. While allegations abound, the Japanese vehemently deny that they are dumping supercomputers. The Japanese position was supported when an investigation by the International Trade Commission of the HARC purchase could not substantiate that dumping had occurred. Since only one Japanese system has been sold in the United States, there is very little data to go on. Consequently, little progress is expected on this issue.

US Purchase of Foreign Systems Contributes to Our Balance-of-Trade Deficit. The nation's balance-of-trade deficit particularly in the computer industry is severe. The Air Force's purchase of a Japanese system further contributes to the balance-of-trade deficit.

Obviously the trade deficit is a serious national economic issue that warrants appropriate action. But its existence is not prima facie cause to adopt widespread protectionist procurement policies/legislation. The entire trade deficit issue and proposed protectionist measures are discussed in greater detail in chapter 5.

US Government Restrictions Put US Firms at a Disadvantage. The US government restricts sales of equipment (e.g., supercomputers) by US corporations to foreign nations, but the Japanese are free to sell their winning systems to any nation they desire. While CDC's market is restricted in the national interests of the US government, the government turns around and purchases computer systems that CDC is forbidden to compete against outside the United States without obtaining an export license.

The concern raised here is that while both the United States and Japan adhere to export restrictions established by the Coordinating Committee for Multilateral Export Controls (COCOM), such restrictions are not applicable to non-Communist-bloc countries such as India. While US firms are further restricted by unilateral government export restraints, competing nations are not similarly constrained and are free to market their products to non-Communist-bloc nations. However, it should be noted that the United States and Japan have entered into an agreement to "consult" with each other before authorizing the sale of a supercomputer to non-COCOM nations.

Obviously the appearance of a double standard is the most frustrating aspect of this issue. In one respect, the US government is telling our high-tech corporations that their products are so good that our military security would be endangered if they should fall into the wrong hands. However, as a reward for risking their *own internal funds* in the development of their commercial products, supercomputer and other high-tech firms must artificially restrict their market base. Keep in mind that although the government does not provide funding for the development of these supercomputers, it is usually the first in line to buy one to protect national security. So if it were not for the industry risking its own funds, the government would have to go out and contract for someone to build it a supercomputer. Given this unusual "arms-length" relationship when it comes to the development of new systems, one might expect that in return for imposing such market restrictions on a purely commercial firm that the United States dearly needs, the government would attempt to offset the lost revenues by restricting purchases of its supercomputers to the "handcuffed" US sources. The fact that it has not operated under such a policy gives added weight to the concerns of the US supercomputer industry that the continuation of present policies could jeopardize the survival of this industry against relatively unconstrained international competitors. At the same time, the continued viability of the supercomputer industry is critical to national security—notwithstanding present government policies.

Jones did not address several other concerns over foreign-source dependency. These are discussed subsequently.

Global Dominance of the Supercomputer Industry Has Severe National Security Implications. The Japanese have publicly stated their intention to dominate the world supercomputer industry. Should they succeed, there would be severe national security implications for the United States. It has been widely

acknowledged by experts in the information-processing industry that if a nation could effectively monopolize the supercomputer industry in the future—when the power and application capabilities of a single supercomputer will be beyond comprehension—it would certainly hold the key to global economic and technological power.

Although the United States was in a position of global dominance until very recently, the capabilities of relatively "primitive" supercomputers such as the Cray-1 were not enough to make a truly global impact. However, the supercomputers of the future with speeds thousands of times that of a Cray-1 will certainly have significant national security implications. Given the strategic military and economic applications of these systems, any nation that controlled this technology and decided to restrict its export would have a stranglehold over the other nations of the world. Even if the controlling nation's export restrictions were not comprehensive, simply restricting exports to less powerful systems such as "last year's model" could prove effective in maintaining that nation's strategic edge. In fact, many US computer firms have claimed that they are already experiencing a related problem when their foreign chip sources provide chips only after their own nation's demands are satisfied. This practice obviously gives the source nation's computer firms a head start in product development and marketing. In this case, the price the US firms must pay for foreign-source dependency is high as the foreign sources exercise strategic business judgment by withholding chip supplies.

US Defense-Related Systems Could Be Subverted. While classified military weapons are manufactured in highly secure facilities to ensure the integrity of the finished product, commercial end products and spares are not afforded the same level of security. As the US government increasingly pursues the purchase of commercial off-the-shelf products to save on development costs and uses the equipment for highly "sensitive" applications, the integrity of the components will become an area of increasing concern. For example, while a supercomputer used by DOE in its national laboratories is protected once it is installed, it is not similarly protected while it is being manufactured and transported for delivery. The general public has only recently become aware of the disastrous effects of hidden/embedded software instructions designed to "sabotage" the integrity of the data within the host system and to other systems with which it may interface. The three sophisticated system-subversion techniques are identified to provide additional information about this growing threat.

"Trapdoors" are special operating instructions embedded in the operating system that allow knowledgeable individuals to bypass established security procedures and access the system. Such trapdoors are typically used by the system designers to ensure continued access to the system during development just in case the designer accidentally finds himself "locked out" of the system. While standard operating procedure would call for the removal of these trapdoors once the software development has been completed, there are no foolproof safeguards to ensure that this is actually accomplished.[6]

"Logic bombs" are embedded instructions within a software program that are designed to perform automatically a predesignated mission at a prespecified time. For example, a system could be programmed to "die" on a prespecified future date.[7]

"Trojan horses" are similar to logic bombs but have the added danger of being hidden in firmware, thus making them even harder to detect than pure software subversion. Basically, a Trojan horse can be preprogrammed to "manipulate" data without the user's knowledge, thus generating erroneous information. It could lie dormant in an SDI battle management system for years, only to automatically "activate" on indications of an actual attack. It could then manipulate the intercept vectors to ensure failure of the host's defensive systems without the knowledge of system operators. According to Whitfield Duffy, a cryptographer at Bell Northern Research, Inc., "The deepest fear of anyone working in computer security is that there is some unseen flaw whose exploitation can't be perceived."[8]

Although such security threats are not restricted to foreign products, the subversion potential is certainly higher for products manufactured outside of this country. The need for greater assurances of the integrity of commercially produced computer systems that will be used in a "sensitive" defense-related environment may become the most forceful argument for restricting the government's purchase of these products to domestic firms.

Supercomputer Alternatives

While most of the politically charged debate over the need for some form of government action to ensure the continued viability of the domestic supercomputer industry has centered on Cray's and ETA's attempts to ward off the three Japanese competitors, little attention has been paid to the rising status of the minisupercomputer industry. A few of these revolutionary systems are able to achieve power and speed ratings that rival supercomputers for certain applications at a fraction of the cost. Any analysis of the supercomputer sector that ignores the potential of this relatively small but rapidly growing segment of the industry is highly suspect. The difference between conventionally designed mainframe supercomputers such as Cray and highly parallel minisupercomputers is significant. In essence, the conventional approach follows the theory set forth by John von Neuman in the 1940s by solving problems and perform-

ing calculations in a serial process. These supercomputers are noted for their ability to start a detailed operation and methodically perform all required operations in an extremely rapid and orderly sequence.

Over the past two decades, the conventional way to increase the speed of supercomputers has been to simply perform the serial process faster. This has been accomplished incrementally through a combination of hardware and software approaches such as incorporating denser and more efficient semiconductors and other components to reduce the distance electronic data must travel, utilizing larger memories, and developing more efficient software to take advantage of the supercomputer's vector capabilities to perform several different operations on different data sets in a serial operation. For example, the single-processor Cray-2 introduced in 1985 has 12 times the performance capability of the Cray-1, which was introduced in 1976.

As demonstrated by the rather limited performance increase between the Cray-1 and the Cray-2, many experts believe that today's conventional architectures have been optimized to the point where further significant increases in power and speed are unlikely because of limitations on the ability to further compress the size of supercomputers. In fact, today's models can be as small as four feet tall and occupy only 16 square feet of floor space. Simply put, the laws of physics constrain further dramatic performance improvements induced by hardware compression. Barring a dramatic technological breakthrough such as a commercially viable superconducting material discovery, only continued incremental improvements can be expected.

Increasingly, many industry experts—including the Defense Advanced Research Projects Agency (DARPA)—believe the future of high-performance computing is tied to the development of highly parallel supercomputers. Instead of performing operations in sequence through a single powerful processor, parallel systems divide problems into many separate parts and then allocate them to distinct, relatively small processors. These processors can then perform all required operations simultaneously—thereby completing the entire task faster. The theoretical merits of such an approach are particularly appealing to government agencies that have present requirements for supercomputers 1,000 times as powerful as any that exist today. Since many believe such performance increases are not possible on conventional supercomputers, the interest in parallel architectures has risen dramatically over the past few years.

In fact, even Cray and ETA have pursued parallelism in an attempt to increase their performance capabilities. However, rather than using large numbers of small processors, they prefer to use small numbers of large processors. For example, both the ETA-10G and the Cray Y-MP incorporate eight powerful independent full-scale processors. Further, Cray is presently developing a 16-processor model—the Cray-3—which is expected to be introduced in 1989 and may have a performance increase of 100 times the capability of a Cray-1. Not only will parallelism increase Cray's performance factors, but the Cray-3 will also be less than half the size of the Cray-1.

On the other hand, firms involved in highly parallel processing employ hundreds or even thousands of separate microprocessors. As of mid-1988, there are more than a dozen minisupercomputer firms that can be considered commercially viable. Since one of the main variables in any parallel system is the method used for the processors to share information and access to memory, each firm has developed its own distinct architecture to capture its unique method of parallelism. Some advocates of highly parallel processing believe it will be possible to develop a supercomputer capable of operating at one trillion flops (one teraFLOP) by the mid-1990s.

While the hardware aspect of employing large numbers of processors to share the intensive calculations involved in today's complex scientific problems has been largely resolved, there are two software issues that must be satisfactorily addressed before this segment of the industry can compete directly against Cray and ETA across the full spectrum of supercomputing applications. First, the task of developing software to coordinate the actions of multiple processors during program execution is formidable and grows significantly more complex as the number of processors increase. Second, programs must be developed to enable users to salvage their vast investment in existing software, which was not written with parallelism in mind.

It is a formidable task for Cray and ETA to develop the ability to break a given software program into a limited number of segments for simultaneous processing by a small number of advanced processors working in parallel (known as *coarse-grained parallelism*). Consider that by today's standards, it could take a team of software engineers two years to develop one specific workable program for a coarse-grained parallel system.[9] However, the difficulty of breaking a problem down into hundreds or thousands of small segments for simultaneous processing (known as *fine-grain parallelism*) is even greater. Some applications are inherently more parallel than others and are therefore easier to program. For example, when geologists induce the ground shocks to find oil deposits, data is received simultaneously from hundreds of sensors. This processing problem is ideal for highly parallel minisupercomputers. However, most other applications are not as straightforward, and therein lies one of the primary obstacles to widespread use of these systems. In essence, the highly parallel software effort is formidable because the instruction set must direct individual processors to perform different operations simultaneously while avoiding conflicts and limiting the time wasted in unproductive communication among the numerous processors.

This already complex software task is further confounded by the current mind-set of today's programmers. Until the dual-processor Cray X-MP was introduced in 1982, all supercomputer programs were written for a serial mode of operation. According to Robert E. Ewald, vice president for software development at Cray, "What we've [computer programmers] been doing for thirty years is taking a world that operates in parallel and finding ways to make it operate sequentially."[10]

Programmers must now radically change their way of thinking in order to write parallel programs successfully. The fact that billions of dollars worth of single-processor applications software already exists serves as a severe constraint to widespread use of highly parallel minisupercomputers. Unless programmers can develop new methods of converting existing programs efficiently, the expense associated with abandoning already-paid-for software would dissuade most potential customers from buying a highly parallel system. Simply put, a supercomputer, no matter how powerful, is useless to a user if it does not have the required software. As stated by Peter Labe, an analyst with Drexel Burnham Lambert, "All announcements of sophisticated parallel machines are very interesting until you ask what they are going to do with it, and where's the software."[11] The overall complexity of the software development task is exemplified by Cray's decision in late 1987 to terminate its MP project, which called for dozens of processors working in parallel. As a result of both hardware and software problems, the MP project cost estimate had grown from \$50 million to \$100 million, and the projected development time had almost doubled to about eight years.[12] All this was over a proposed system with only 64 processors. Realizing that the project had exceeded its relatively modest financial resources, Cray terminated the program. Steve Chen had headed this project and decided to leave Cray as a direct result of the program's cancellation. As previously mentioned, Chen is currently continuing with the program at his own newly formed corporation—with funding help from IBM.

Despite all of the difficulties, highly parallel minisupercomputers are commercially marketed today. However, they have not been able to challenge the high end of the supercomputer market that the conventional models control. Instead, they are filling the niche between the VAX-type minisupercomputers and the Cray-type supercomputers. At the upper end of their niche, they are used for the limited number of applications where they can outperform the more general-purpose Cray and ETA systems.

Generally speaking, the difference between supercomputers and minisupercomputers is distinct. While Cray and ETA market models that can generally perform all types of applications quickly, minisupercomputers are more specialized machines that perform certain applications very quickly but may not be very efficient at most other applications. Therefore, given the dramatic performance increases in certain targeted applications that the upstart minisupercomputer firms have been able to demonstrate over the past few years, these firms have been able to directly challenge the upper-tier supercomputer firms only over a limited spectrum of supercomputing. However, despite these specialized performance capabilities, most long-term users of conventional supercomputers are not willing to expend the time and money to rewrite their existing software for these new machines unless the performance gains are truly substantial. Therefore, due to the extensive software difficulties inherent in fine-grained parallelism, most experts believe such models will be limited to new customers with applications "tailor-made" for the parallel approach, not current supercomputer owners seeking to increase existing capabilities.

While the US computer industry has been marketing multiprocessor supercomputers and minisupercomputers for several years, the Japanese had not introduced even a single multiprocessor supercomputer or minisupercomputer by mid-1988. Although they have been pursuing such R&D, they have apparently concentrated most of their effort on developing the world's fastest single-processor supercomputers. This approach is supported by Dr Sidney S. Fernbach, chairman of the Institute of Electrical and Electronic Engineers (IEEE) Supercomputer Committee, and Gene Amdahl, a pioneer of the computer industry, who both believe that future supercomputer dominance belongs to those firms that first develop the world's fastest single-processor systems and then pursue limited parallelism.[13]

If this is their strategy, the Japanese may be well on their way to establishing industry dominance despite their apparent lack of attention to parallelism to date. In order to appreciate where Japanese supercomputers currently stand in respect to speed, one must understand the concept of a "clock-cycle." One clock-cycle represents the time it takes a processor to initiate, process, and complete a function before the next iteration begins. The best supercomputers operate in cycles measured by single-digit nanoseconds (n/s)—one-billionth of a second. As of mid-1988, the world's fastest single-processor supercomputer was the Hitachi S820/80 with a 4 n/s clock-cycle. Needless to say, the Japanese are marketing state-of-the-art systems—not deeply discounted "second-tier" equipment.

The Government's Role

DARPA is the federal government's chief proponent of the highly parallel approach to supercomputing. Since 1983 DARPA has been helping to fund selective nonconventional approaches to supercomputing under its Strategic Computing Initiative program. The program's goal is to accelerate supercomputing

technology through large-scale parallel processing. Perhaps the showpiece of DARPA's efforts to date has been the 65,536 small-processor connection machine built by Thinking Machines of Cambridge, Massachusetts. The optimal use for this machine, which is the prototype for a million-processor model, is to perform calculations on problems where the problem data set can be partitioned for simultaneous operations such as image and signal processing. As of the end of 1987, 16 machines had been ordered by the likes of Martin Marietta, Massachusetts Institute of Technology, Yale University, and the US Naval Research Laboratory.[14]

In addition to funding commercial concerns, DARPA has helped initiate computer science laboratories at various universities that will concentrate their efforts on parallel-processor development. These schools are Carnegie-Mellon University, Stanford University, Syracuse University, University of California at Berkeley, and the University of California's Information Sciences Institute.[15]

Supercomputers/Minisupercomputers and the Future

At least once every few months the media touts the introduction of a highly parallel system that claims to be "faster than a Cray" while costing significantly less. As alluded to earlier, stories are misleading. The world's five primary supercomputer firms market general-purpose machines that can perform applications across the full spectrum of supercomputing. Some of the applications run faster than others, but all programs run very quickly. On the other hand, the highly parallel systems are not as versatile. They are usually designed to run specific types of applications very quickly. Consequently, while some can indeed outperform conventional supercomputers in several applications, they may not even come close on others.

The entire process of comparing the performance capabilities of all types and sizes of supercomputers and minisupercomputers is a science that is fraught with subjectivity. Even though institutions such as the Argonne National Laboratory have developed measurement standards for a wide variety of applications, the numerous categories of rankings should not be used as a basis for buying a specific model unless the selected computer measures well in the exact application for which it will be used.

Even if we could accurately measure speeds of the various models for all the applications we intend to use, there are many other related factors that can sway the decision as to which model is the "right" choice. For instance, differences in working memory, the availability of an extensive software library, software performance, system reliability and maintainability, upgrade potential, and manufacturer support all can significantly influence the choice of which system to purchase.[16]

When all these factors are considered, one can readily understand why Cray has remained the supercomputer of choice for most purchasing agents. Its popularity is specifically due to its established customer base, high research and development ratios, a diversified product and price range, a solid service organization, and a name that has almost become synonymous with the term *supercomputer*.[17] Based on this assessment, it would appear as though Cray should be able to maintain its distinct lead in the industry for the foreseeable future. However, one must acknowledge the amazing ability of the Japanese to capture 25 percent of the world market in only five years.

Unlike Cray, ETA faces immediate problems primarily due to its scarcity of software and the lack of an entrenched customer base. Therefore, of the two firms, ETA is more vulnerable to Japanese competition and must work hard to ensure its survival.

All factors considered, Cray and ETA have not exhibited the uncompetitive signs typical of "failing" US industries. Although many may argue that these two firms have not been aggressive enough—an easy criticism to make when your own money is not on the line—Cray and ETA/CDC have certainly demonstrated the best of the American entrepreneural spirit and should be commended for their contributions to national security.

While the immediate future belongs to the five supercomputer powers (Cray, ETA, NEC, Fujitsu, and Hitachi), one eye must be kept on the minisupercomputer firms as they seek to continue the remarkable strides they have achieved since the early 1980s. They now offer commercially available, low-cost alternatives to the expensive conventional supercomputers—albeit over a narrow spectrum of applications. Their potential to rival or even surpass the likes of Cray is tied directly to their ability to manage the software development effort associated with controlling large numbers of processors operating in parallel. However, high-performance computing experts—such as Dr Stephen Squires, assistant director of the Information Science and Technology Office at DARPA—believe that highly parallel supercomputers will define the state of the art in supercomputing in the 1990s.[18] Consequently, America's national security interest may not be directly dependent on the ability of Cray and ETA to hold off the three Japanese giants. Since the Japanese apparently have not devoted a significant amount of resources to highly parallel systems, the United States appears to hold a definitive lead in this increasingly important segment of the supercomputer industry.

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Chapter 5

Facing the Challenge

This study has demonstrated that the United States faces two significant economic problems that will significantly affect our national security in the future. At the macrolevel, our decreasing competitive capabilities in the world's new economic order seriously jeopardize the nation's economic well-being, and if not corrected, this problem will in turn reduce our military capabilities. At the microlevel, we are faced with a decision regarding our supercomputer industry—a critical sector for our national security. This chapter completes the analysis of the supercomputer issue and then closes with a review of the broader national competitiveness issue.

Legal Environment

Obviously any DOD initiatives to resolve either the foreign-source dependency or the broader competitiveness issue must conform to the existing statutory requirements. A quick synopsis of the relevant statutes is provided below.

In accordance with the Buy American Act of 1933, DOD has been required to favor domestic firms by increasing the estimated cost of foreign bids by 50 percent. (Civilian agencies have been required to add between 6 and 12 percent.)[1]

In 1950 the Defense Production Act was passed, providing DOD with the authority to enact vital readiness programs directed toward maintaining the national defense base for peacetime, surge, and national emergency requirements. Title I of the act establishes production priority ratings that require contractors to give priority to appropriately rated defense orders. Title III of the act authorizes a variety of financial incentives to encourage private-sector investment to increase production in areas critical to national security19—particularly where foreign-source dependence is a concern.[2]

Since 1948 the United States has been one of 80 nations subscribing to the General Agreement on Tariffs and Trade (GATT). The purpose of this general agreement has been to "reduce tariffs, eliminate nontariff measures, and remove other trade obstacles that handicap the free flow of international trade."[3] In 1979 the United States was one of 20 signatories to the International Agreement on Government Procurement, which in effect extended the principle of free trade to government purchases. It established specified procedures that signatory governments would follow when making purchases of a wide range of specified commodities valued in excess of 150,000 special drawing rights (SDRs)—which are a composite of five currencies roughly equivalent to $149,000. In accordance with the agreement, US government agencies are required to waive the "Buy American" preferences with respect to "covered" purchases.[4]

In addition to the GATT waivers, the United States has entered into memorandums of understanding (MOUs) with allied nations whereby the provisions of the Buy American Act have been similarly waived.

Another significant piece of legislation is the Competition in Contracting Act (CICA) of 1984, which requires that

> executive agencies, except under limited and well-defined circumstances, use full and open competition in making contracts to acquire property or services. Full and open competition is accomplished only when (1) all qualified vendors are allowed and encouraged to submit offers on federal procurements, and (2) a sufficient number of offers is received to ensure that the government's requirements are filled at the lowest possible cost.[5]

It is significant to note that CICA continues to allow DOD to maintain or establish specific sources of supply for a particular item when it is considered to be in the interest of national defense. In the language of a comptroller-general decision, "The normal concern of maximizing competition is secondary to the needs of industrial mobilization."[6] Not only can DOD restrict a purchase to a specific firm, but it can also restrict a purchase to "domestic sources" when that is considered to be in the nation's security interests. The statutes therefore serve as a foundation for the government initiatives discussed below.

The Supercomputer Question

Four specific products have taken on disproportionate importance as symbols of the ongoing trade friction between the United States and Japan. These are semiconductors, beef, citrus goods, and, of course, supercomputers. Undoubtedly, resolution of the differences between our two nations is critical for global order as many experts warn that the situation could degenerate into a global trade war.

Beyond the obvious necessity to maintain good relations with our allies, the United States has a vested

economic and security interest in maintaining a domestic capability to develop the world's most powerful computers. In our present trade environment, these goals often seem to be mutually exclusive.

The need for a careful balancing of interests makes the supercomputer issue take on unique importance. Specifically, although this technology sector has an insignificant direct effect on the overall balance of trade, it has nevertheless captured the attention of high-level political figures in both countries. In fact, the United States Congress entered the fray in 1987 and specifically prohibited DOD from purchasing foreign (i.e., Japanese) supercomputers without prior approval. Ironically, this action occurred just a few months after the two countries had successfully concluded discussions aimed at opening Japan's supercomputer market to US firms.

Any decision regarding the continuation of the broad-based purchase restriction should be based on an objective analysis of the following factors: technological competitiveness, installed base advantage, currency value advantage, inherent flexibility of technical evaluations, other technological factors, barriers to entry, and "big-picture" ramifications.

Technological Competitiveness

At the present time, there is relatively little technological difference between the supercomputer models marketed by the five major manufacturers (Cray, ETA, NEC, Fujitsu, and Hitachi). Since several years of development effort are required between the introduction of a particular firm's successive models, a slight advantage enjoyed by a given firm today may be eliminated by another firm's model tomorrow—which may be surpassed by yet another firm when it introduces a new model. Regardless of which company holds the lead today, the technological differences are not currently great enough for a firm to hold what could be considered an insurmountable lead over the others since that lead could be readily eliminated by another firm's new model. In effect, one can say that over the short run the five firms are presently involved in a good "horse race."

However, one disconcerting aspect of the race has been the ability of the three Japanese conglomerates to come from out of nowhere and control one-quarter of the installed base in just five years. Up until Steve Chen's decision to leave Cray and IBM's subsequent decision to back Chen's new company, the ability of the domestic industry to hold off the financially powerful Japanese firms over the long run was a very serious concern. Today, however, even though Chen is certainly several years away from introducing a commercially viable product, just the fact that IBM has become a player in the market enhances the prospects of continued American dominance in the supercomputer market.

Installed Base Advantage

As discussed in chapter 4, Cray presently controls almost two-thirds of the world's supercomputer base. Given such advantages as its extensive software library and the aversion of current customers to switch to a competitor's model for what would likely be an insignificant performance improvement Cray is well positioned to continue its market lead in the immediate future. Although certainly not in as good a position, ETA does have a decent Cyber 205 customer and software base to work from. On the other hand, since software development is both a costly and time-intensive effort, the three Japanese manufacturers have their work cut out for them before they can take away established Cray and ETA/CDC customers.

Where the US firms are immediately vulnerable is among new customers who often pursue new supercomputer applications where no firm has the software advantage. In that case, factors such as software tools and hardware prices take on increasing importance. Since the Japanese firms do not have an inherent advantage in software tools, that area should enjoy fair competition. The biggest concern, therefore, is the pricing aspect. Given their understandable business need to establish a wide customer and software base, it would make financial sense for the Japanese firms to offer significant discounts over the short run (e.g., five to eight years) in order to stimulate sales. While this might not be enough incentive for established customers to change brands given their massive investment in software, large system discounts might be sufficient to convince a new customer to "try out" a Japanese system.

Further, the Japanese marketing approach takes on a unique twist in that many of their customers lease systems rather than purchase them outright. Because the US firms do not offer lease plans, financially strapped customers such as universities find the Japanese lease alternatives far more attractive than the American purchase proposals. Since the US firms either will not or cannot match such Japanese offers, they allege unfair behavior by the Japanese. However, such charges are very difficult to prove because there is no American baseline with which to compare the lease proposals (which may also include lease-back arrangements of computer time by the seller). This is said to have occurred in the HARC acquisition discussed in chapter 3 in which dumping charges could not be substantiated. Beyond having to prove that below-cost sales have been made, the investigation must also make a finding that damage to the domestic industry has resulted from the dumping action. Such a finding is next to impossible given the fact that the US firms control three-quarters of the world's installed base.

Such claims of unfair competition will be difficult if not impossible to substantiate—especially for systems installed outside of the United States (frequently estimated as 50 percent of the future market). Therefore,

it is in the domestic industry's interest for the governments of the United States and Japan to establish bilateral "rules of the game" to ensure fair competition in the supercomputer market. Without such rules, should the Japanese perceive that the lucrative US public-sector market is closed to their products by either overt or covert restrictions, they will certainly play "hardball" in the remaining open markets. With their "deep pockets," there is little doubt the Japanese would succeed if that was their goal—IBM notwithstanding.

Currency Value Advantage/Flexibility of Technical Evaluations

Since all current supercomputer competitors seek to develop and manufacture the entire system on their home territory, the comparative value of their respective currency provides a significant competitive advantage/disadvantage. Based on the most recent currency swing of the 1985–88 period, the US firms now maintain a significant advantage that should serve to constrain Japanese system-discounting practices.

In the absence of the congressionally mandated purchase restrictions, DOD supercomputer acquisitions would be subject to technical evaluation criteria under "full and open competition." Since such criteria for a complex technology would not usually place cost as the most important evaluation criterion, the technical merits and other pertinent factors of all proposed systems could be carefully scrutinized and weighed before the best system for the government's needs is selected. For example, one such factor would be the costs associated with converting existing software to a new system. If a Japanese firm receives the highest source-selection rating based on our preestablished evaluation criteria and if the spares-provisioning and maintenance-support language discussed in chapter 4 are incorporated in the contract, there should be no *reasonable* objection to awarding the contract to that firm.

Other Technological Factors

As discussed in chapter 4, the dramatic increases in the performance of highly parallel systems over the past few years serves to hedge our bets on future dominance in supercomputing. In effect, all our eggs are not in the conventional basket. Based on the foresight and financial risk-taking of American entrepreneurs—along with selective funding by DARPA—the United States is well positioned should highly parallel systems be the basis for supercomputing dominance in the future.

Barriers to Entry

The discussions above provided arguments why DOD does not need to be *overly* concerned about Cray's and ETA's competitive prospects over the short run. Such optimism is constrained by the factors discussed below.

Being a player in the supercomputer market is a very expensive proposition. Even with CDC's recent experience with its Cyber 205 line, ETA is believed to have invested more than $100 million in development funds before it had even introduced its first supercomputer. Notwithstanding the commitment of firms like ETA to succeed in the market, many experts question whether the global market can sustain five or six major firms—not even considering perhaps dozens of minisupercomputer firms. Consequently, the United States may not be able to afford to lose one of its key players since few other firms would consider entering this high-stakes and often cutthroat market.

Beyond the financial barrier to entry, one must also consider the technical barrier. Again, despite ETA's experience and Cyber 205 know-how, it still took ETA more than four years to introduce its low-end, dual-processor system—and another year before it could introduce its top-end, eight-processor system. Given these technological barriers, if the United States were to wait until one of its supercomputer firms is in deep trouble, it could take years before it or another firm could hope to catch up to the rest of the field.

Further, the Japanese firms have found that it is hard for a new player to obtain market acceptance. Many existing and prospective customers are comfortable with Cray's track record and are often unwilling to jeopardize their users (and maybe their careers) on an unknown entity. In fact, if it were not for Japanese national loyalty in buying Japanese supercomputers, those firms would have very few sales. Again, the key concern is that by the time it becomes obvious that a firm is in trouble, it may be too late to take decisive action.

"Big-Picture" Ramifications

The United States and Japan are deeply involved in multisector trade discussions that certainly have the potential to get ugly. The trade tensions of the past few years have already made their mark, as a recent poll of Japanese junior high school students demonstrated. The majority of the students believed Japan "was more likely to go to war with the United States than any other nation—including the Soviet Union."[7] Given this environment, the supercomputer issue has generated an unbelievable amount of visibility. Considering the possible ramifications of this issue on the "big picture," I do not believe the United States can afford to appear unreasonable and continue such blatant protectionist measures in what is still a very healthy domestic sector. In fact, in terms of its profitability rate, Cray was the most profitable computer company in the United States during 1987.[8] (Undoubtedly this was due to Cray's

virtual monopolistic hold on the market over the past decade. Increased competition should constrain Cray's pricing practices and keep it technologically competitive.)

Based on a consideration of all the rationale discussed above, DOD must certainly recommend that the foreign-purchase restriction not be continued. This recommendation is based on the belief that domestic firms should be very competitive under DOD technical evaluations and that most of the arguments against the purchase of foreign systems discussed in chapter 3 can be overcome with contractual safeguards.

The exception to such full and open competition for DOD's supercomputer acquisitions should be when the system will be used in a classified environment. Given that such applications requiring the power of a supercomputer inherently involve the nation's most-guarded secrets, it would be prudent to minimize the security risks associated with foreign-source systems. Restricting such acquisitions to domestic sources would not be inconsistent with our obligations under GATT, which provides an exception for procurements "indispensable for national security or for national defense purposes."[9] Certainly we would acknowledge the right of the Japanese to pursue the same policy.

Therefore, the national security risks of trade-war-induced tensions between the United States and Japan must be an important consideration when determining what our supercomputer procurement policy should be. Considering that DOD will be seeking increased access to technology and products developed by our trading partners during these times of austere budgets, cordial trade relations are critical to the maintenance of technological superiority against our military adversaries.

Certainly, there are instances where DOD will have to protect strategic industries and bear the brunt of allied criticism. In fact, when intervention is required, we should pursue such cases vigorously before Congress feels the need to get involved. Only by demonstrating that DOD is willing and able to take the required action can we reasonably hope that Congress will leave national security issues for DOD to resolve.

Concurrently, we must not allow ill-advised protectionist measures to damage our relationships with our allies unnecessarily. As documented in chapter 1, the nation enjoys a trade *surplus* in defense goods. In fact, when one scrutinizes DOD's fiscal year 1986 expenditures, only 1.4 percent of the $160 billion spent was for foreign products.[10] Based on this good record, Congress should not use DOD as the "whipping boy" for sending signals on broader trading problems.

DOD must actively monitor the health of industrial sectors crucial to our national security. While advocating open competition (except for classified applications) in the supercomputer sector, we should closely monitor the competitiveness of our systems in world markets. Particular emphasis should be placed on the "neutral" European market, where emerging dominance trends will certainly be clearer than in either the United States or Japan.

Neither Cray nor ETA expects or wants direct government financial assistance (because of the "strings" attached to such help). Instead, they would prefer that the government act as a knowledgeable customer and purchase the systems that they introduce into the market. Besides this arms-length relationship, Cray and ETA expect the agencies primarily responsible for trade issues, such as the Office of the US Trade Representative and the Department of Commerce, to ensure that the globe's competitive "playing field" remains as level as possible. Both Cray and ETA believe they are competitive against the Japanese in a fair competition.

Notwithstanding the arms-length relationship previously discussed, the government should consider a directed-source purchase of an ETA-10. This action could be readily justified as necessary to maintain an alternative source in the interest of industrial mobilization pursuant to Federal Acquisition Regulation (FAR) 6.302-3.

Having addressed the supplier side of the supercomputer issue, we should not ignore the user side. While dominance in supercomputer hardware is significant, its usefulness is limited by the availability of trained and experienced users. In an attempt to develop a base of such skilled practitioners, the National Science Foundation has funded five supercomputer centers at leading universities over the past several years. However, this program is presently in financial jeopardy. Not only have funds not been appropriated for several additional centers as originally envisioned, but operation and maintenance funding contributions for the existing centers have been drastically reduced.

Here we have yet another example of the American inability to follow through on a strategic program. Given the high stakes involved in this sector, the country must be in a position to take advantage of our technological capabilities. Both existing and planned NSF centers must be funded. Not only will this enhance our ability to tap a valuable national resource, it will also provide ETA and Cray with new potential markets.

DOD Initiatives to Confront the Broader Competitiveness Issue

Given the tremendous size of DOD's annual procurement budget—$160 billion—it is imperative that our acquisition force fully comprehend significant threats to our national security. Unquestionably, foreign-source dependence is one of those threats.

Educated Acquisition Force

Acquisition schoolhouses such as the Defense Systems Management College (DSMC), the Industrial

College of the Armed Forces (ICAF), and the Air Force Institute of Technology (AFIT) must include this vital issue in their curricula. Studies such as this one could serve as resources in the coverage of this vital area.

The acquisition community must recognize that today's military forces exist in an environment far different than the one faced by our comrades-in-arms only a generation ago. Consider that

> perhaps for the first time in the history of social man, sheer size of territory, resources, and population is of declining economic, and in some ways, even military importance. Economic and military power are increasingly determined by the products of science, technology, know-how, entrepreneurial flexibility, and innovative skills.[11]

The competitiveness of our nation's commercial sector is becoming increasingly important to DOD. Stephen S. Cohen and John Zysman point out in their book, *Manufacturing Matters*, that the overall costs of DOD's weapon systems are greatly reduced by the existence of an extensive and vibrant economic infrastructure. Leading-edge commercial technologies have provided the basis for customized defense products at a much lower cost than if DOD had to establish/maintain the infrastructure itself.[12] Consider that the semiconductor industry discussed in chapter 2 directly or indirectly invests $2 billion annually in R&D efforts to improve the products and processes that DOD is increasingly dependent on.[13]

Until very recently, DOD had the luxury of not having to be overly concerned about the status of our commercially based economic infrastructure. We were generally only concerned about those industrial/technological sectors with direct military applications—and then only about their ability to "surge" in time of war. However, as the nation's overall economic capability weakens as a result of global competition, the pertinent question is no longer can it surge in wartime but can it remain viable during peacetime?

Beyond this issue of direct support for military capabilities lies a deeper concern over the "ripple" effect of lost industrial/technological capabilities on the nation's overall economic power. As the rest of the world continues to catch up economically and technologically, our ability to shape events elsewhere on the globe via political-economic-military initiatives is drastically eroding. Considering that history has shown time and time again the mutual dependence of a nation's military and economic strengths, DOD must undertake whatever reasonable initiatives it can to help ensure the nation's economic health. Since DOD absorbs some 10 percent of the nation's manufacturing output while employing more than a quarter of its scientists and engineers, it certainly has some leverage in providing the leadership necessary to ensure American industrial/technological competitiveness.[14]

In fact, following the leadership of Under Secretary of Defense Robert Costello, DOD has already funded several strategic initiatives designed to ensure the viability of key industrial/technological sectors. These fiscally modest programs range from the Industrial Modernization Incentives Program (IMIP), which encourages improvements in manufacturing capabilities that increase productivity and quality, to the establishment of an office dedicated to taking action when our commercial sector fails to provide and maintain the capability to produce items needed by DOD. In such cases, DOD can invoke the authority vested in Title III of the Defense Production Act of 1950 to provide incentives for the private sector by "guaranteeing" a market for specified products. We must ensure that these initiatives do not fade away during the Bush administration.

However, there are several less-drastic actions that DOD can pursue on a day-to-day basis to ensure not only the competitiveness of our military forces but also the competitiveness of our commercial sector. These initiatives include using commercial off-the-shelf items wherever possible, considering commercial benefits before approving R&D efforts, emphasizing quality in production, measuring foreign-source dependency, and resisting inappropriate protectionist pressures.

Technology Transfer

As discussed in chapter 1, there are two serious issues concerning DOD and technology transfer. One involves overcontrol of dual-use exports. The other involves the legal transfer of advanced technologies to foreign nations under separate licenses or as part of offset arrangements. Certainly the defense community must take a more balanced and pragmatic approach in the maintenance of its export control lists. Admittedly, the export control process has been accelerated due to automation, but the fundamental issue of the scope of the list has not been satisfactorily resolved. Because many of our strategic high-tech firms face increased foreign competition in the global marketplace, DOD must not handicap our economic livelihood unnecessarily under the shortsighted banner of "military security." As demonstrated in chapters 1 and 2, the national security is increasingly dependent on a strong economy to support the defense budget.

This is, of course, a complex issue with many sides to the argument. The Allen Report, published under the title *Balancing the National Interest*, thoroughly analyzes the problem and sets forth numerous recommendations. While many government officials may disagree with some of the report's findings, it is critical that those responsible for the export control process fully comprehend the national security implications of their actions.

The related issue of technology transfer to allies who are also economic competitors also deserves careful attention. Clearly the one-way flow of information must cease. The advanced know-how that is transferred has more often than not been the result of high levels of government R&D funding—while the sums

received for the technology are a fraction of the cost of its development. In an era in which the nation's competitive ability is at risk, such technology transfers could prove to be disastrous over the long run.

Thankfully, there are indications that our leadership is awakening to this danger. Gregg A. Rubinstein, a former deputy director of the Mutual Defense Assistance Office at the US Embassy in Tokyo, notes that "projects that do not entail clear reciprocity in technology transfers may not survive such scrutiny" (critical scrutiny among trade and defense agencies as well as Congress).[15] Such a review process must not falter.

Increased Use of Commercial Products

Although recommendations to use commercial products have been made in the past, such an approach received a major boost when it became one of the Packard Commission's keystone recommendations.[16] Soon thereafter, DOD Directive 5000.1, *Major and Non-Major Defense Acquisition Programs*, directed that off-the-shelf commercial products should be used whenever possible. Of course, simply codifying such an approach does not ensure its success when it must be carried out at the local level. DOD should ensure that its acquisition personnel understand that the underlying rationale goes beyond simply providing state-of-the-art systems at reduced costs and ensuring a speedy, low-risk acquisition.

Equally important, such action helps our commercial sector remain competitive in the global marketplace. For example, a significant amount of DOD's communications, automatic data-processing equipment, and other electronics acquisitions—which are particularly susceptible to rapid obsolescence—should be purchased from commercial entities. Not only does this process save DOD time, money, and manpower in the acquisition process, it helps industry do the same and allows it to concentrate resources on turning out the best products for an increasingly homogeneous military and commercial customer base.

Overreaching R&D

Americans are widely known for wanting the best and wanting it now. DOD is no exception. However, as noted in chapter 1, DOD's effective monopolization of the nation's R&D funds places the commercial sector at a decided disadvantage in the global marketplace. Certainly the applicability of commercial applications should not be the overriding concern of our R&D programs, but it should be a factor in the selection process.

In order to facilitate an enhanced mind-set within the acquisition community, acquisition regulations should require that a section of the acquisition plan specifically address the potential for commercial applications as a result of the proposed R&D effort. Additionally, requests for proposal should require that offerers articulate their intended approaches to derive the maximum practical commercial value from the contract. This will help reverse the trend of the past few decades and drive DOD acquisitions back to commercially based firms and away from the overly specialized and marginally competitive defense industry.

Emphasis on Quality

One of the primary causes of America's competitive problems is the continued perception throughout the world—including the United States—that our products are qualitatively inferior. Consider, for example, that a 1987 survey of its members by the Korea Traders Association revealed that only 6 percent of the respondents considered American goods superior to Japanese ones. This factor is significant because the Koreans (and many other nations) have surplus dollars from their positive trade balance with the United States but cannot find anything they are willing to buy from us.[17]

Many contend that DOD has contributed to our nation's quality problems. We have institutionalized the concept of an "acceptable quality level" in our military standards—a euphemism for an "acceptable level of failure." Instead of constantly striving for improved quality like many of our global competitors, the defense industry has became complacent and gives DOD just what we ask for—an "acceptable" level of quality. These less-than-stringent requirements are passed on to subcontractors, who in turn pass them on to their subcontractors until many sectors of American industry are infected with this concept of "acceptable" quality.

To illustrate the economic impact of this problem, consider the quality consciousness of the Japanese. The failure rate of their semiconductors is one per 1,000,000, compared to one per 100,000 for American chips. Unbelievably, this obsession with quality recently allowed a Japanese firm to dare launch a mega-million-dollar *uninsured* communications satellite.[18] Undoubtedly, quality pays for itself many times over.

Meanwhile, the average American taxpayer has been exposed to numerous instances of DOD's expenditure of vast sums of money for weapon systems that do not work as required but are accepted by the services anyway. This ethic of "it doesn't meet specifications but we'll take it anyway" is a poor example to set for the rest of the nation. Until DOD embraces the concept that quality is just as important as cost and schedule, industry—and, in turn, the nation—will continue to be known for shoddy products that cannot be relied on to work when needed.

Manufacturing Matters

Many look to the transition to a service economy to be the United States' salvation, just as the transition

from agriculture to industry in the nineteenth century boosted the nation's economy. This "wishful thinking" ignores the fact that we did not lose our agricultural capabilities as we have our industrial capabilities. Rather, the agriculture labor market shakeout occurred as we automated the process and increased output. This is not what is happening in our industrial sector today. We have either moved our operations to foreign nations or simply abandoned many sectors crucial to our future competitiveness. Even the relatively low-paying service jobs that have been created to replace the lost manufacturing jobs are in one way or another dependent on the nation's manufacturing infrastructure.[19]

Many critics have blamed the Competition in Contracting Act for its overemphasis on awarding contracts on a low-cost basis, thus accelerating the outsourcing of manufacturing and assembly operations to offshore facilities to the detriment of our industrial base. Somehow, the nation must balance the pursuit of low-cost contracts with the need to maintain the industrial infrastructure necessary for our national security. This is surely a complex issue DOD cannot even attempt to resolve until we can analyze the extent of the problem.

Since a great deal of foreign-source dependency is buried at the subsystem and component level, DOD should designate selected weapon-system acquisitions as test cases for measuring our level of dependence and, in turn, our level of logistical risk should a national emergency require accelerated production and maintenance. Each contractor's proposal should require the identification of *all* foreign parts to be incorporated within the weapon system, along with the rationale used by the contractor in specifying that source. Only by reviewing such proposals can DOD get a true feel for the magnitude of the problem and its likely causes.

Of course, we cannot and should not want to build a Fortress America where we are totally self-sufficient. However, there are certainly many strategic technologies that *must* be based in the United States for national security reasons. Whether such US-based sources are American or foreign owned is not as important a factor as having such a base in the first place. Again, however, we cannot address the challenge adequately until we know the extent of our dependency. Getting such a handle on the problem must be an immediate DOD initiative.

National Initiatives

Of course, most of the nation's competitiveness problems are bigger than DOD and require attention at the national level. But even in these instances, DOD is a key participant. Resistance to ill-advised protectionist measures is one of the more important issues requiring governmentwide coordination.

Educating America

Given the 12 years or more that it takes for improved basic education to show results, it is imperative that the nation pursue "excellence-in-education" initiatives immediately. The government of our chief economic rival believes that it has a vested interest in ensuring that its population has the basic academic skills required to contribute as productive members of society. Japan's central government therefore takes an active role to ensure that these skills are taught efficiently.[20] If we are to compete successfully in the new economic order, we must do the same.

Resistance to Protectionist Pressures

As global competition continues to grow, special interest groups can be expected to increasingly pressure members of Congress and DOD to enact legislation that protects their "vital" industries from "unfair" foreign competition. Only informed leaders will be able to evaluate these vocal and emotional appeals pragmatically. When he addressed a conference of industry executives, former Secretary of Defense Weinberger used a quote from Shakespeare's *Julius Caesar* to convey his feelings regarding broad-based protectionism: "The fault, dear Brutus, is not in our stars, but in ourselves."[21]

Specifically, labor-intensive American industries continue to blame low wages in foreign countries for their poor performance. While this may be true in the newly industrialized countries such as South Korea and Taiwan, a 1987 International Monetary Fund estimate concluded that American unit labor costs were lower than those in Japan, West Germany, Canada, and Italy and were equivalent to those of the United Kingdom and France.[22]

A frequently heard complaint from industry is that our trade deficit with Japan is primarily due to their closed market for our goods and that the deficit would improve dramatically if we could only force open the Japanese market. However, W. Allen Wallis, under secretary of state for economic and agricultural affairs, has noted that even if the Japanese market were entirely open, the $60-billion annual trade deficit would only improve by $10–$15 billion—an amount equal to our "closed/restrained" market for certain Japanese goods (e.g., automobiles).[23]

Undoubtedly the easiest, fastest, and often most politically acceptable solution is to erect protectionist barriers to save endangered industries. In fact, the increased use of Title III authority under the Defense Production Act of 1950 will certainly be necessary if the nation is to save strategic industries currently in jeopardy. However, such action will prove to be only "Band-Aid" remedies unless they are accompanied by initiatives that address the underlying causes of our competitive problems. According to Deputy Defense Secretary William Howard Taft IV, "We [as a nation]

must examine and correct investment practices, profit concepts, ownership trends, capitalization requirements, and other procedures that have constrained development of productivity enhancing processes and technologies."[24]

Based on a thorough analysis of the above factors, government intervention must be predicated on sound, well-thought-out recovery programs proposed and financially backed by those industries requesting help. The bottom line is that Title III actions or specific congressional protectionist legislation should not be considered as a form of "industrial welfare" but rather as a helping hand to industries willing to make the sacrifices and the effort necessary to regain their competitiveness.

Controlling the "Twin Deficits"

To date, the practical reality of our deteriorating economic position in the global environment apparently has not sunk in with our national leadership. Many of the world's economists have noted the fact that despite our position as the world's largest debtor, the United States continues to think and act like the creditor it once was. Conversely, Japan, the world's largest creditor, continues to think and act like the debtor it once was. As these two nations begin to assume roles more in keeping with their new economic means, the global ramifications will be profound.

For instance, consider the implications of our $150-billion-per-year budget deficits. Driven largely by the trade deficit in manufactured goods and debt-servicing costs to foreigners, the long overdue initiatives to reverse the process will certainly reduce the level of growth of the average American's standard of living. In fact, according to Lester C. Thurow, a Nobel laureate in economics and dean of the Sloan School of Management at MIT, the nation will soon have to "give up" 1 percent of its overall GNP growth just to service our existing debt burdens.[25] So, instead of a reasonable 3-percent growth rate in a given year, Americans will only reap the benefits of an anemic 2-percent growth as the remaining growth is sent overseas.

Up until now, Americans have adapted to high real (face value minus inflation) interest rates and, more recently, increased prices of imported goods as a result of the weakened dollar. However, as the nation's financial squeeze becomes greater in the future—when the nation is inevitably forced to face its economic problems—a key DOD concern will be the enormous ramifications on DOD's funding. In fact, DOD has already begun to feel the pain as a result of only token measures to get the nation's financial house in order.

As the federal government struggles to balance the budget, more pain is sure to follow since there are very few discretionary areas of the budget that can be cut before defense. This is because most federal funding falls under the entitlements heading—and those areas all have powerful and vocal constituents that are directly affected by program cuts (e.g., Social Security recipients). Not only must the leadership make significant cuts, it must also find funds to combat the drug problem, reinvigorate our educational system, and correct other problems in our nation's competitive infrastructure.

All in all, the nation and DOD face numerous fiscally constrained decisions. This should have been apparent several years ago, but DOD and the administration chose to ignore the warning signs. Now DOD must suffer through greater "withdrawal" pains than if it had acknowledged the unattainability of out-year budget projections at an earlier date. It will be in DOD's self-interest to ensure that the present and future cutback management process works as smoothly as possible so that the industrial/technological base that the nation depends on for its present and future national security emerges in relatively healthy shape.

National Leadership

Presidential Science Adviser William Graham echoes the need for the United States to get its collective act together:

> One of the government's most important roles is to act as a catalyst—to make sure that industry understands that, in today's highly competitive international environment, it is essential we pursue technologies before they are fully developed in the laboratories of our competitors. Other countries have been striving to catch up with the United States, as they recovered from the destruction of World War II. They had to move into advanced technology at a pace faster than ours. Several of these countries have caught up with us, and are now accustomed to innovating and advancing technology more rapidly than we are.[26]

As Ellen L. Frost, a former deputy assistant secretary of defense for international economic and technology affairs, points out in her book *For Richer, For Poorer: The New US-Japan Relationship*, the Japanese government is adept at ensuring that the "invisible hand of the marketplace is guided in the right national direction."[27] Japan currently has more than 30 national R&D programs that many experts believe will enable the Japanese to challenge the United States in most areas of basic research and advanced technology by 1990.[28] Although some of its methods for doing so are considered as unfair, there can be no doubt that the Japanese government is doing what all successful governments must do—provide *leadership* to the nation. Frost derides the absence of an executive branch position charged with "identifying and communicating long-term trends and incorporating them into the policy-making process."[29]

Without such executive branch leadership, the nation is subject to the "knee-jerk" responses by Congress to the latest constituent crisis. For example, when the agricultural sector hit particularly bad times in 1986, Congress approved subsidized exports to the Soviet Union—thereby undercutting sales by many of our allies. Australians were particularly incensed since

agriculture is their primary export business. So while the United States cries about unfair practices of the Japanese, it takes similar actions that hurt innocent allies. Such callous, shortsighted behavior is indicative of US strategic trade policy. Without a coherent long-term competitiveness strategy, the United States will not be able to sustain whatever leadership positions it currently holds—let alone recapture those it has already lost.

Controlling the Greed Factor

Often industry can create its own problems without any help from DOD. This is particularly true if one concentrates on the shortsighted greed factor of many of our commercial firms. For example, one would expect the declining dollar to make a significant difference in the competitiveness of American goods, but empirical evidence from past periods of a depreciating dollar shows that corporate greed often causes our corporations to increase prices to reap larger profits rather than hold prices in order to recapture lost market shares.[30] While our corporations are raising their prices, foreign firms bite the bullet and hold down their prices to retain market share. Consequently, few experts predict a dramatic decline in our trade deficit. Instead, many predict increased inflation as domestic firms increase their prices in concert with foreign competitors.

This has been particularly true in the automobile sector, where the "big three" have actually lost market share to the Japanese despite a 100-percent appreciation in the value of the yen over the past several years. A US International Trade Commission study estimates that American consumers paid an extra $8.5 billion in 1984 alone as a consequence of import restrictions that were enacted in a futile attempt to give domestic manufacturers a chance to regain their competitiveness.[31] Unbelievably, our domestic automobile industry is presently pressing for *additional* import restraints. Congress must not fail to send a clear signal that the behavior of the industry while under protection was unconscionable, and it should resist all pressure to continue the charade.

National Industrial/Technological Policy

It is therefore imperative that the political leadership reject calls to protect the low-tech "sunset" industries of the past, and instead concentrate on long-term measures to renew American competitiveness by transitioning to the high-tech "sunrise" industries of the future. The nation must abandon its crisis-driven ad hoc strategies that change with each new administration. This American tendency to "wing it" in the global competitive environment will not work against increasingly sophisticated competitors. Some people would argue that this is simply a reflection of the American independent spirit and preference for a market-driven economy. Of course, the simple retort is, "Look at world trade statistics and you'll see it isn't working." More important, these numbers are dismal even though we have enjoyed the benefits of "cheap" oil over the past few years. As our dependence on imported oil surpasses the levels of the 1970s, a substantial price hike would have devastating effects on inflation, the trade deficit, and the rest of the economy.

Encouraged by their government, Japanese firms are already abandoning the "sunset" shipbuilding and automobile industries as they increasingly move many of their production operations to such low-labor-cost nations as the United States. In turn, they train displaced workers to take on the high-tech jobs of the future. In support of this policy, Japan has adopted a national strategy called the Technopolis Concept, which is establishing 19 high-tech cities where Japanese firms will concentrate their tax-incentive efforts on such "sunrise" sectors as biotechnology, fine ceramics, electronics, robots, mechatronics (electronic machinery), computers, and software.[32]

Many observers would advocate that we do nothing, believing that the Japanese are simply imitators and that now that they have "caught up" with the United States in many areas of technology, they will not be able to continue their current pace because their culture stifles creative talent. In this view, the Technopolis Concept is doomed to failure and the American penchant for creativity will help us regain our lost position. Thomas J. Murrin, a former top-level executive at Westinghouse and currently a professor at Carnegie-Mellon University, disagrees. He notes that just as Japan imported much of its technology from the United States as it built its industrial base, we did the same by importing technology from Europe. Only after we had established our industrial base did we develop sophisticated universities and first-class research centers. The Japanese can be seen following this same process, as evidenced by their ability to turn out more engineering PhDs per capita than the United States.[33]

When viewed from an R&D competitiveness perspective, not only do the Japanese outeducate us, they will soon outspend us as well. Consider that if one excludes military-related R&D, the absolute value of Japanese investment in commercial R&D will exceed ours by 1990.[34] All things considered, the Japanese are certainly better positioned in this increasingly technological world to perform the R&D required to pursue economic dominance.

Abandoning the "Not-Invented-Here" Syndrome

Even as they seek to increase their technological prowess by sinking increasingly larger amounts of their corporate profits into their R&D programs, the Japanese continue to seek outside scientific insights by

meticulously reviewing scientific publications from other nations. Their highly educated and bilingual work force is constantly monitoring world market trends and looking for that bit of obscure outside information that will help catapult ongoing research into the breakthrough category. In fact, MITI considers it part of its charter to gather all available information on current technological innovations occurring in the West and distribute this data to the appropriate Japanese firms.[35]

Needless to say, American firms are poorly positioned to take advantage of technological breakthroughs occurring outside of the United States. Unlike the Japanese, many American researchers adhere to the "not-invented-here" syndrome and are not willing to expend the effort to try and learn from other nations. Even if they were willing, the overwhelmingly monolingual Americans cannot decipher such foreign publications—and no government or private-sector entity does this to any significant extent. Pitifully, the existing government approach is a two-person staff at the Commerce Department's National Technical Information Service.[36]

Given the importance of scientific communication in the research process, it is imperative that US researchers have access to translated versions of Japanese and other nations' scientific and technical publications. The government could either provide incentives for the establishment of private means—the preferred approach—or, as a last resort, take the activity in house.

Again, however, American industry must show greater initiative than it has demonstrated so far. Consider the following case. Shoji Tanaka is one of Japan's technology visionaries whose credentials include his successful prodding of his government to pursue national R&D efforts during the 1970s in such strategic markets as semiconductors, fiber optics, and optical disks. Of course, Japan now dominates these markets. In his present assault on superconductivity, Tanaka leads a MITI-sponsored consortium made up of scientists from 44 of Japan's top 100 industrial concerns. Although invited to join, American firms such as IBM have refused, complaining that the cost of membership is too high and that they were already working on the issue on their own. Tanaka views this apparent American aloofness with concern, believing that such benign hostility will bring on a rush of Japanese nationalism that will benefit no one.[37]

Conclusions

Unquestionably, America's relative power in both military and economic spheres has changed dramatically over the past several decades. Where our nuclear and economic capabilities once ensured that we could influence the course of world events, we now find our nuclear arsenal for all intents and purposes checkmated by the Soviets. Further, the world's economic leadership is shifting toward the Japanese. While most individuals have perceived the change in military relations, many are still not cognizant of the magnitude of the changes occurring in the economic arena. For example, consider the degree of control of the global banking system, one indicator of a nation's economic power. Not surprisingly, the 10 largest banks in the world are all Japanese, while the United States does not have a single bank in the top 25.[38]

With the advent of huge budget and trade deficits that are increasingly being financed by the US government borrowing abroad, the resulting deflated value of the dollar will inevitably lead to a far lower rate of growth in the standard of living in the United States than for many of the world's other industrialized nations. As the automatic mechanisms of Gramm-Rudman-Hollings II (or some successor legislation) kick in, DOD will surely take some big hits. DOD must be concerned with the effect of the nation's economic woes on its budgets.

In the past, the United States has generally subscribed to the principle that the federal government should limit fiscal policies to such ends as controlling interest rates, inflation, the rate of economic growth, and the unemployment level. Direct market intervention has usually been limited to protectionist measures to prolong the agony of "sunset" industries instead of investing in the "sunrise" industries that will ensure our future competitiveness.

While some observers claim that a national industrial policy smacks of central planning Soviet style, few realize that our government already pursues a limited form of such planning. We have implemented many divergent industrial policies through numerous tax law provisions that provide special treatment for certain sectors of the economy. The problem with our past approaches has been that they are usually an uncoordinated compilation of special-interest initiatives with little if any regard for a coherent and comprehensive national competitiveness strategy. This is a shame, because the nation's tax system is perhaps the most efficient mechanism for encouraging particular initiatives, such as capital investment, employee training/retraining, increases in R&D, and changing consumer consumption rates.

However, with the current twin budget and trade deficits, the historical "hands-off" approach may no longer be feasible. As mentioned in earlier chapters, the United States appears to lack the capital investment and educational infrastructure required to be optimistic about its future. While we seek to find answers to these problems, America's demographic time bomb is ticking. As "baby boomers" reach middle-age and retire, their sheer number and their increased life expectancy will impose intolerable retirement and health care burdens on wage earners of the twenty-first century. Con-

sider that in 1945 there were 42 workers for every retiree in the Social Security system. Presently the ratio is 3:1, and by the middle of the next century it will be 2:1.[39] Additionally, as life expectancy increases, so will national health care expenses. Who will pay for all these social costs and the interest payments on the national debt, and how will these burdens affect the defense of our nation? The nation has developed a "spend-now" attitude, and the result is that our personal savings rate is now one-third that of West Germany's and only one-quarter that of Japan's.[40] Instead of the tax-and-spend policies of the past, we have embraced the policy of spend and borrow. In the past, our "can-do" spirit usually enabled us to find a relatively painless way to solve our problems—but we usually had a good economic foundation to start from. That is no longer the case.

Although Japan's national economic and industrial policies have certainly worked so far, there is no presumption that a duplication of such policies will succeed in the United States. Rather, the point is that we have not even *tried* to do something to ensure our future competitiveness. Perhaps the nation will not be moved to action until a significant global event shocks the nation—à la the Sputnik launch in 1957. Then again, perhaps the emergence of the Japanese as a challenger to our economic leadership is just such a shock—but we have been either too complacent, too arrogant, or too uninformed to react.

I am convinced that the very first step the national leadership *must* take is to admit that the nation does indeed face severe economic problems and that they will not go away if we ignore them. Concomitantly, the government must educate the public to the problems the nation faces in the future and inform citizens that the federal government's primary responsibilities are to maintain a national defense capability and to guarantee constitutional freedoms—not to provide social benefits for the masses. At a minimum, individual citizens must reacquire the American work ethic and step up to bear greater responsibility for their own welfare—including saving for retirement.

For its part, the executive branch must provide the courageous leadership necessary to reverse our decline—to include tax increases when they are found to be necessary. Congress, in turn, has to stop "pork-barrel" legislation and start making some hard budget-cutting decisions based on the good of the nation—not the home district. The military services need to accelerate efforts to *eliminate parochialism*, and, perhaps most of all, we must start putting fiscal reality behind some of our weapon system program decisions.

Perhaps it is appropriate to conclude with the following view of our future:

> It is not difficult to be pessimistic about the likelihood that the United States and its trading partners will act to stave off future economic disaster. If past trends continue, wishful thinking about surpluses in services and agriculture will be combined with measured doses of protection and inflation. . . Washington will talk about accelerating its productivity growth and competitiveness but will not adopt concrete measures to do so. And living standards will fall as America is forced to pay back the resources it borrowed to live beyond its means in the 1980s.[41]

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